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Head First

C#

A Learner's Guide to
Real-World Programming
with C# and .NET

Andrew Stellman
& Jennifer Greene

Free PDF of chapters 1 to 4

This PDF has everything in the first 300+ pages of the book.



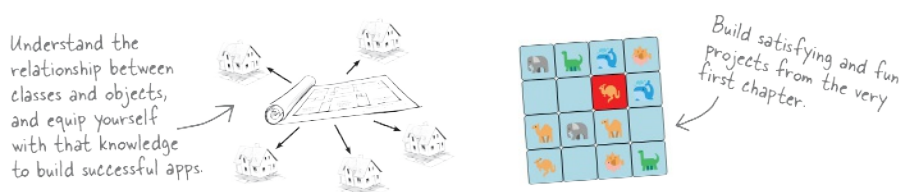
A Brain-Friendly Guide

Head First

C#

What will you learn from this book?

Create apps, games, and more using this engaging, highly visual introduction to C#, .NET, and software development. You'll learn how to use classes and object-oriented programming, create 3D games in Unity, and query data with LINQ. And you'll do it all by solving puzzles, completing hands-on exercises, and building real-world applications. Interested in a development career? You'll learn important development techniques and ideas—just like many others who've learned to code with this book and are now professional developers, team leads, coding streamers, and more. There's no experience required except the desire to learn. And this is the best place to start.



What's so special about this book?

If you've read a Head First book, you know what to expect: a visually rich format designed for the way your brain works. If you haven't, you're in for a treat. With this book, you'll learn C# through a multisensory experience that engages your mind—rather than a text-heavy approach that puts you to sleep.

"Thank you so much! Your books have helped me to launch my career."

—**Ryan White**
Game Developer

"In a sea of dry technical manuals, *Head First C#* stands out as a beacon of brilliance. Its unique teaching style not only imparts essential knowledge but also sparks curiosity and fuels passion for coding. An indispensable resource for beginners!"

—**Gerald Versluis**
Senior Software Engineer
at Microsoft

"Andrew and Jennifer have written a concise, authoritative, and, most of all, fun introduction to C# development."

—**Jon Galloway**
Senior Program Manager on
the .NET Community Team
at Microsoft

C#/.NET

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Praise for Head First C#

“In a sea of dry technical manuals, *Head First C#* stands out as a beacon of brilliance. Its unique teaching style not only imparts essential knowledge but also sparks curiosity and fuels passion for coding. An indispensable resource for beginners!”

—**Gerald Versluis, Senior Software Engineer at Microsoft**

“*Head First C#* started my career as a software engineer and backend developer. I am now leading a team in a tech company and an open source contributor.”

—**Zakaria Soleymani, Development Team Lead**

“Thank you so much! Your books have helped me to launch my career.”

—**Ryan White, Game Developer**

“If you’re a new C# developer (welcome to the party!), I highly recommend *Head First C#*. Andrew and Jennifer have written a concise, authoritative, and most of all, fun introduction to C# development. I wish I’d had this book when I was first learning C#!”

—**Jon Galloway, Senior Program Manager on the .NET Community Team, Microsoft**

“Not only does *Head First C#* cover all the nuances it took me a long time to understand, it has that Head First magic going on where it is just a super fun read.”

—**Jeff Counts, Senior C# Developer**

“*Head First C#* is a great book with fun examples that keep learning interesting.”

—**Lindsey Bieda, Lead Software Engineer**

“*Head First C#* is a great book, both for brand-new developers and developers like myself coming from a Java background. No assumptions are made as to the reader’s proficiency, yet the material builds up quickly enough for those who are not complete newbies—a hard balance to strike. This book got me up to speed in no time for my first large-scale C# development project at work—I highly recommend it.”

—**Shalewa Odusanya, Principal**

“*Head First C#* is an excellent, simple, and fun way of learning C#. It’s the best piece for C# beginners I’ve ever seen—the samples are clear, the topics are concise and well written. The mini-games that guide you through the different programming challenges will definitely stick the knowledge to your brain. A great learn-by-doing book!”

—**Johnny Halife, Partner**

“*Head First C#* is a comprehensive guide to learning C# that reads like a conversation with a friend. The many coding challenges keep it fun, even when the concepts are tough.”

—**Rebeca Dunn-Krahn, Founding Partner, Sempahore Solutions**

Praise for Head First C#

“I’ve never read a computer book cover to cover, but this one held my interest from the first page to the last. If you want to learn C# in depth and have fun doing it, this is THE book for you.”

—**Andy Parker, fledgling C# Programmer**

“It’s hard to really learn a programming language without good, engaging examples, and this book is full of them! *Head First C#* will guide beginners of all sorts to a long and productive relationship with C# and the .NET Framework.”

—**Chris Burrows, Software Engineer**

“With *Head First C#*, Andrew and Jenny have presented an excellent tutorial on learning C#. It is very approachable while covering a great amount of detail in a unique style. If you’ve been turned off by more conventional books on C#, you’ll love this one.”

—**Jay Hilyard, Director and Software Security Architect, and author of *C# 6.0 Cookbook***

“I’d recommend this book to anyone looking for a great introduction into the world of programming and C#. From the first page onward, the authors walk the reader through some of the more challenging concepts of C# in a simple, easy-to-follow way. At the end of some of the larger projects/labs, the reader can look back at their programs and stand in awe of what they’ve accomplished.”

—**David Sterling, Principal Software Developer**

“*Head First C#* is a highly enjoyable tutorial, full of memorable examples and entertaining exercises. Its lively style is sure to captivate readers—from the humorously annotated examples to the Fireside Chats, where the abstract class and interface butt heads in a heated argument! For anyone new to programming, there’s no better way to dive in.”

—**Joseph Albahari, inventor of LINQPad, and coauthor of *C# 12 in a Nutshell* and *C# 12 Pocket Reference***

“[*Head First C#*] was an easy book to read and understand. I will recommend this book to any developer wanting to jump into the C# waters. I will recommend it to the advanced developer that wants to understand better what is happening with their code. [I will recommend it to developers who] want to find a better way to explain how C# works to their less-seasoned developer friends.”

—**Giuseppe Turitto, Director of Engineering**

“Andrew and Jenny have crafted another stimulating Head First learning experience. Grab a pencil, a computer, and enjoy the ride as you engage your left brain, right brain, and funny bone.”

—**Bill Mietelski, Advanced Systems Analyst**

“Going through this *Head First C#* book was a great experience. I have not come across a book series which actually teaches you so well.... This is a book I would definitely recommend to people wanting to learn C#.”

—**Krishna Pala, MCP**

Praise for the Head First Approach

“I received the book yesterday and started to read it...and I couldn’t stop. This is definitely très ‘cool.’ It is fun, but they cover a lot of ground and they are right to the point. I’m really impressed.”

—**Erich Gamma, IBM Distinguished Engineer, and coauthor of *Design Patterns***

“One of the funniest and smartest books on software design I’ve ever read.”

—**Aaron LaBerge, SVP Technology & Product Development, ESPN**

“What used to be a long trial and error learning process has now been reduced neatly into an engaging paperback.”

—**Mike Davidson, former VP of Design, Twitter, and founder of Newsvine**

“Elegant design is at the core of every chapter here, each concept conveyed with equal doses of pragmatism and wit.”

—**Ken Goldstein, Executive VP & Managing Director, Disney Online**

“Usually when reading through a book or article on design patterns, I’d have to occasionally stick myself in the eye with something just to make sure I was paying attention. Not with this book. Odd as it may sound, this book makes learning about design patterns fun.

“While other books on design patterns are saying ‘Bueller...Bueller...Bueller...’ this book is on the float belting out ‘Shake it up, baby!’”

—**Eric Wuehler**

“I literally love this book. In fact, I kissed this book in front of my wife.”

—**Satish Kumar**

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Unity Game Development Cookbook, 2nd Edition
by Paris Buttfield-Addison, Jon Manning, and Tim Nugent

Programming C# 12 *by Ian Griffiths*

Functional Programming with C# *by Simon J. Painter*

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We love this book so much!



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Head First Object-Oriented Analysis and Design

Head First Programming

Head First Python

Head First Software Architecture

Head First SQL

Head First Swift

Head First Web Design

Head First C#

Wouldn't it be dreamy if there was a C# book that's more fun than memorizing a dictionary? It's probably nothing but a fantasy...



Andrew Stellman
Jennifer Greene

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Head First C#

by Andrew Stellman and Jennifer Greene

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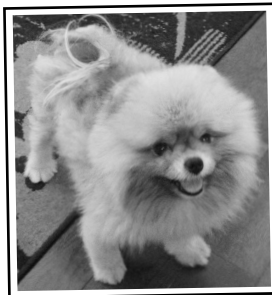
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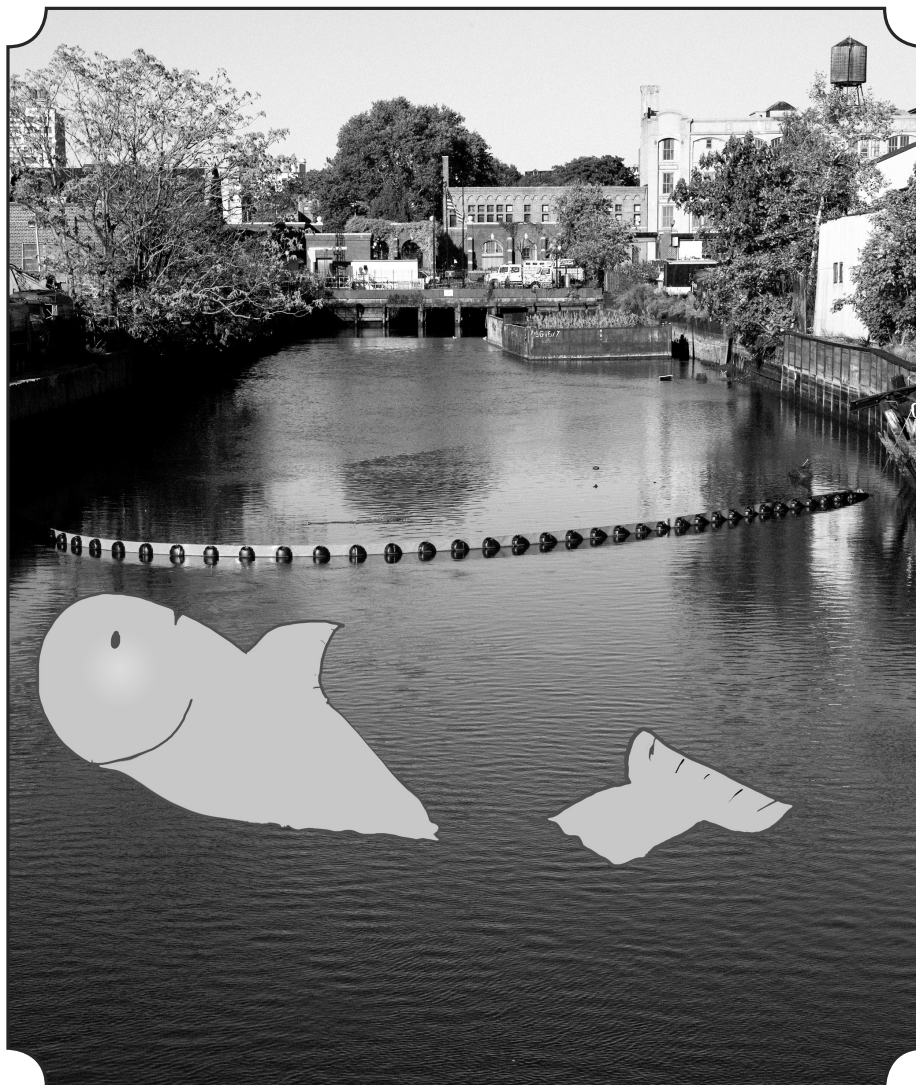
No pigeons, ducks, ostriches, elephants, dogs, hippos, chameleons, bees, clowns, aliens, game masters, jewel thieves, or superheroes were harmed in the making of this book.

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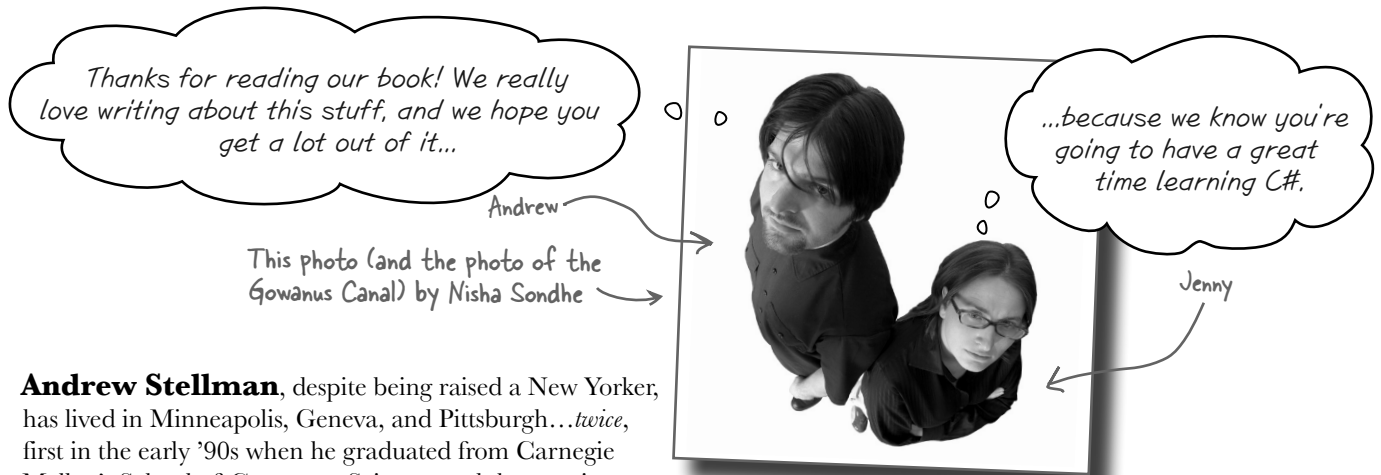
[2024-12-19]

*This book is dedicated to the loving memory of Sludgie the Whale,
who swam to Brooklyn on April 17, 2007.*



*You were only in our canal for a day,
but you'll be in our hearts forever.*

the authors



Andrew Stellman, despite being raised a New Yorker, has lived in Minneapolis, Geneva, and Pittsburgh...*twice*, first in the early '90s when he graduated from Carnegie Mellon's School of Computer Science, and then again in the early 2000s while he and Jenny were starting their consulting business and writing their first book for O'Reilly.

Andrew's first job after college was building software at a record company, EMI-Capitol Records—which actually made sense, as he went to LaGuardia High School of Music & Art and the Performing Arts to study cello and jazz bass guitar. He and Jenny first worked together at a company on Wall Street that built financial software, where he was managing a team of programmers. Over the years he's architected large-scale real-time backend systems, managed large international software teams, been a senior vice president at a major financial firm, and consulted for companies, schools, and organizations, including Microsoft, the National Bureau of Economic Research, and MIT. He's had the privilege of working with some pretty amazing developers during that time, and likes to think that he's learned a few things from them.

When he's not writing books, Andrew keeps himself busy writing useless (but fun) software, playing (and making) both music and video games, practicing krav maga, tai chi, and aikido, and owning a crazy Pomeranian.

Jenny and Andrew have been building software and writing about software engineering together since they first met in 1998. Their first book, *Applied Software Project Management*, was published by O'Reilly in 2005. Other Stellman and Greene books published by O'Reilly include *Beautiful Teams* (2009), *Learning Agile* (2014), *Head First Agile* (2017), and their first book in the Head First series, *Head First PMP* (2007), now in its fourth edition.

They founded Stellman & Greene Consulting in 2003 to build a really fascinating software project for scientists studying herbicide exposure in Vietnam veterans. In addition to building software and writing books, they've consulted for companies and spoken at conferences and meetings of software engineers, architects, and project managers.

Learn more about them on their website, *Building Better Software* (<https://www.stellman-greene.com>).

Jennifer Greene studied philosophy in college but, like everyone else in the field, couldn't find a job doing it. Luckily, she's a great software engineer, so she started out working at an online service, and that's the first time she really got a good sense of what good software development looked like.

She moved to New York in 1998 to work on software quality at a financial software company. She's managed teams of developers, testers, and PMs on software projects in media and finance since then.

Jenny has traveled all over the world to work with different software teams and build all kinds of cool projects.

She loves traveling, watching Bollywood movies, reading the occasional comic book, playing video games, and hanging out with her Australian Labradoodle.

Table of Contents (Summary)

	Intro	xxix
1	Start building apps with C#: <i>Build something great...fast!</i>	1
2	Variables, statements, and methods: <i>Dive into C# code</i>	65
	<i>Unity Lab 1: Explore C# with Unity</i>	111
3	Namespaces and classes: <i>Organizing your code</i>	127
4	Data, types, objects, and references: <i>Managing your app's data</i>	189
	<i>Unity Lab 2: Write C# Code for Unity</i>	257
5	Encapsulation: <i>How objects keep their secrets</i>	271
6	Inheritance: <i>Your object's family tree</i>	325
	<i>Unity Lab 3: GameObject Instances</i>	403
7	Interfaces, casting, and is: <i>Making classes keep their promises</i>	415
8	Enums and collections: <i>Organizing your data</i>	473
	<i>Unity Lab 4: User Interfaces</i>	539
9	LINQ and lambdas: <i>Get control of your data</i>	553
10	Reading and writing files: <i>Save the last byte for me</i>	621
	<i>Unity Lab 5: Raycasting</i>	673
11	Captain Amazing: <i>The Death of the Object</i>	687
12	Exception handling: <i>Putting out fires gets old</i>	731
	<i>Unity Lab 6: Scene Navigation</i>	763

Table of Contents (the real thing)

Intro

Your brain on C#. Here *you* are trying to *learn* something, while here your *brain* is doing you a favor by making sure the learning doesn't *stick*. Your brain's thinking, "Better leave room for more important things, like which wild animals to avoid and whether naked snowboarding is a bad idea." So how *do* you trick your brain into thinking that your life depends on knowing C#?

Who is this book for?	xxx
We know what you're thinking	xxxix
Metacognition	xxxix
Bend your brain into submission	xxxv
Read me	xxxvi
The technical review team	xxxviii
Acknowledgments	xl

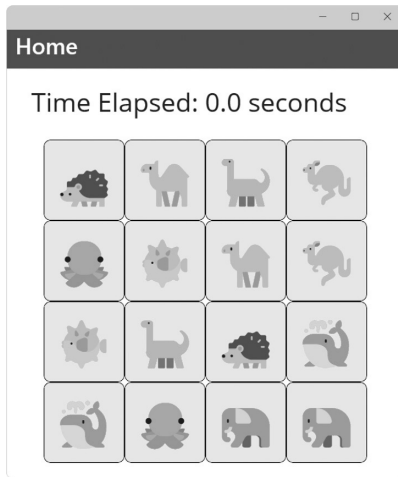
start building apps with C#

1

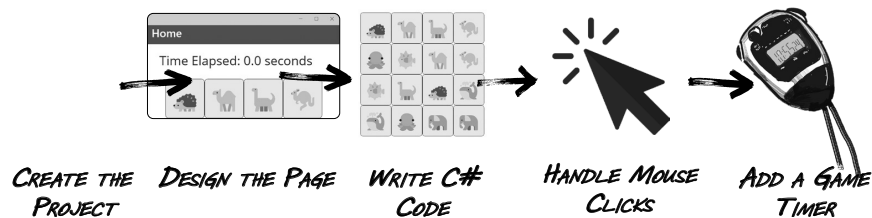
Build something great...fast!

Want to build great apps...right now?

With C#, you've got a modern programming language and a **valuable tool** at your fingertips. And with **Visual Studio**, you've got an amazing development environment with highly intuitive features that make coding as easy as possible. Not only is Visual Studio a great tool for writing code, it's also a **really effective learning tool** for exploring C#. Sound appealing? **Let's get coding!**



Learn C#...and learn to become a great developer	2
Write code and explore C# with Visual Studio	3
Install Visual Studio Community Edition	4
Run Visual Studio	5
Create and run your first C# project in Visual Studio	6
You can use Visual Studio Code with <i>Head First C#</i>	12
Create and run your first project in Visual Studio Code	14
Set up Visual Studio Code for the next project	17
Let's build a game!	18
Create a .NET MAUI project in Visual Studio	22
Run your new .NET MAUI app	24
MAUI apps work on all of your devices	25
Start editing your XAML code	27
Use a FlexLayout to make a grid of animal buttons	34
Write C# code to add the animals to the buttons	38
Run your app!	46
Visual Studio makes it easy to use Git	51
Add C# code to handle mouse clicks	52
Add a timer to your game's code	60
Finish the code for your game	62

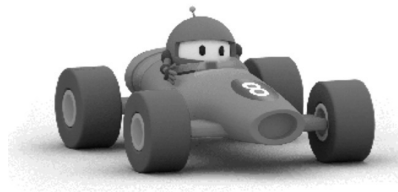
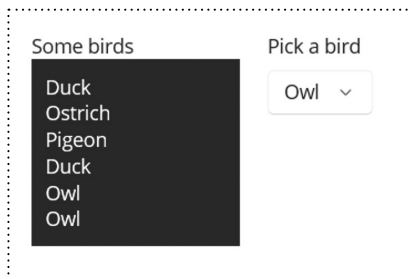


variables, statements, and methods

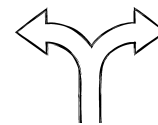
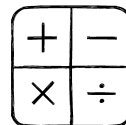
Dive into C# code**2****You're not just an IDE user. You're a developer.**

You can get a lot of work done using the IDE, but there's only so far it can take you.

Visual Studio is one of the most advanced software development tools ever made, but a **powerful IDE** is only the beginning. It's time to **dive in to C# code**: how it's structured, how it works, and how you can take control of it...because there's no limit to what you can get your apps to do.



Take a closer look at the files in your console app	66
Statements are the building blocks for your apps	68
Statements live inside methods	69
Your methods use variables to work with data	70
Generate a new method to work with variables	72
Add code that uses operators to your method	73
Use the debugger to watch your variables change	74
Use code snippets to help write loops	76
Use operators to work with variables	77
if statements make decisions	78
Loops perform an action over and over	79
Controls drive the mechanics of your user interfaces	88
Other controls you'll use in this book	89
Create a new app to experiment with controls	91
Explore your new MAUI app and figure out how it works	92
Add an Entry control to your app	96
Add properties to your Entry control	97
Make your Entry control update a Label control	98
Combine horizontal and vertical stack layouts	103
Add a Picker control to display a list of choices	104

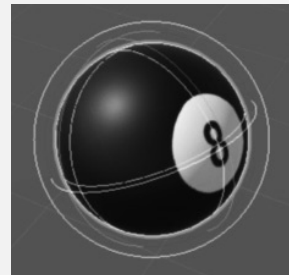
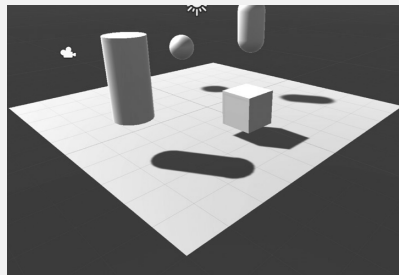


Unity Lab 1

Explore C# with Unity

Welcome to your first **Head First C# Unity Lab**. Writing code is a skill, and like any other skill, getting better at it takes **practice and experimentation**. Unity will be a really valuable tool for that. In this lab, you can begin practicing what you've learned about C# in Chapters 1 and 2.

Unity is a powerful tool for game design	112
Download Unity Hub	113
Use Unity Hub to create a new project	114
Your scene is a 3D environment	116
Unity games are made with GameObjects	117
Use the Move Gizmo to move your GameObjects	118
The Inspector shows your GameObject's components	119
Add a material to your Sphere GameObject	120
Rotate your sphere	123
Get creative!	126

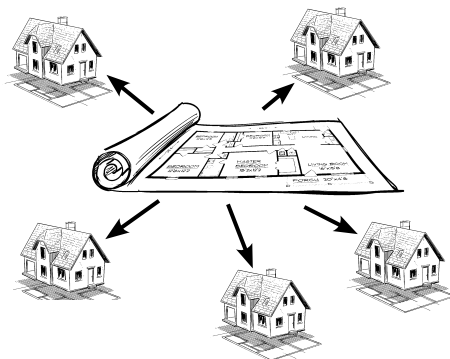


namespaces and classes

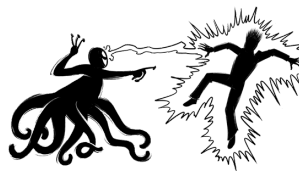
Organizing your code**3****Great developers keep their code and data organized.**

What's the first thing you do when you're creating an app? You think about what **it's supposed to do**, whether you're solving a problem, creating a game, or just having fun.

But it's not always obvious how individual statements fit into your app's bigger picture...and that's where **classes** come in. They let you **organize your code** around the features you're creating and the problems the app needs to solve. Classes can help you **organize your data** too, by using them to create **objects** that represent any "thing" your app needs to know about—and the classes that you design serve as "blueprints" for the objects used in your app.



Classes help you organize your code	128
Some methods take parameters and return a value	130
Let's build an app that picks random cards	132
Create an app with a Main method	134
Use Quick Actions to remove unnecessary using lines	138
Convert between namespace styles	139
Use the new keyword to create an array of strings	140
Build a paper prototype for a classic game	148
Build a MAUI version of your random card app	150
Reuse your CardPicker class	154
Add a using directive to use code in another namespace	155
You use a class to build an object	159
A better solution for Ana...brought to you by objects	161
An instance uses fields to keep track of things	165
Use intuitive class and method names	172
Build a class to work with some guys	178
Use the C# Interactive window or csi to run C# code	188



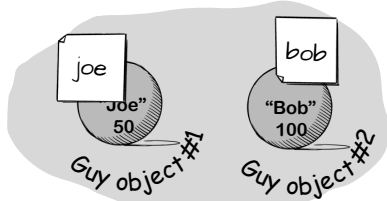
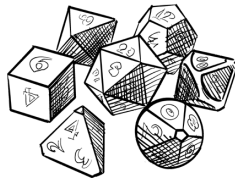
data, types, objects, and references

Managing your app's data

4

Data and objects are the building blocks of your apps.

What would your apps be without data? Think about it for a minute. Without data, your programs are...well, it's actually hard to imagine writing code without data. You need **information** from your users, and you use that to look up or produce new information to give back to them. In fact, almost everything you do in programming involves **working with data** in one way or another. In this chapter, you'll learn the ins and outs of C#'s **data types** and **references**, see how to work with data in your program, and even learn a few more things about **objects** (guess what...objects are data, too!).



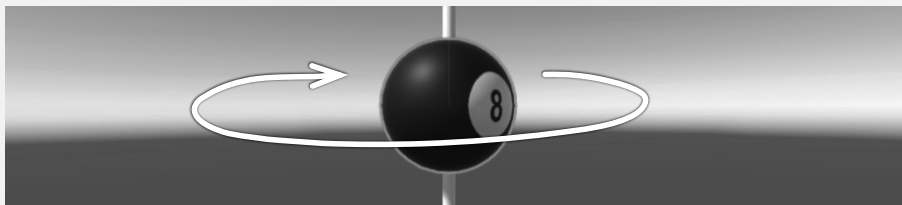
A variable's type determines what kind of data it can store	192
C# has several types for storing integers	193
Let's talk about strings	195
A literal is a value written directly into your code	196
Casting lets you copy values that C# can't automatically convert to another type	202
C# does some conversions automatically	205
Use reference variables to access your objects	222
References are like sticky notes for your objects	223
Multiple references and their side effects	226
Two references mean TWO variables that can change the same object's data	233
Objects use references to talk to each other	234
Arrays hold multiple values	236
null means a reference points to nothing	241
Use the string? type when a string might be null	243
Welcome to Sloppy Joe's Budget House o' Discount Sandwiches!	246
Grid controls	248
Create the Sloppy Joe's menu app and set up the grid	250
Use the SetValue method to change a control's semantic properties	256

Unity Lab 2

Write C# Code for Unity

Unity isn't *just* a powerful, cross-platform engine and editor for building 2D and 3D games and simulations. It's also a **great way to get practice writing C# code**. In this lab, you'll get more practice writing C# code for a project in Unity.

C# scripts add behavior to your GameObjects	258
Add a C# script to your GameObject	259
Write C# code to rotate your sphere	260
Add a breakpoint and debug your game	262
Use the debugger to understand Time.deltaTime	263
Add a cylinder to show where the Y axis is	264
Add fields to your class for the rotation angle and speed	265
Use Debug.DrawRay to explore how 3D vectors work	266
Run the game to see the ray in the Scene view	267
Rotate your ball around a point in the scene	268
Use Unity to take a closer look at rotation and vectors	269
Get creative!	270



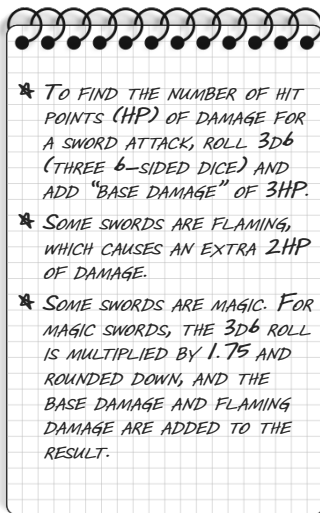
encapsulation

5

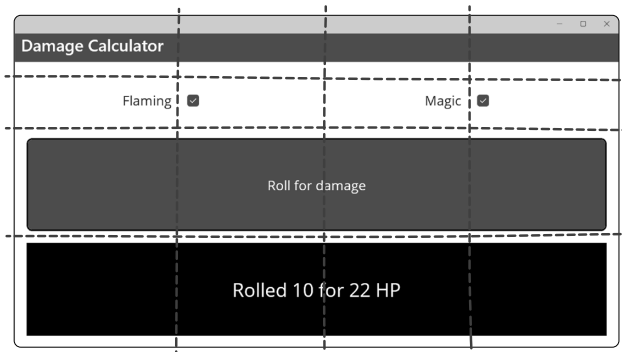
How objects keep their secrets

Ever wished for a little more privacy?

Sometimes your objects feel the same way. Just like you don't want anybody you don't trust reading your journal or paging through your bank statements, good objects don't let **other** objects go poking around their fields. In this chapter, you're going to learn about the power of **encapsulation**, a way of programming that helps you make code that's flexible, easy to use, and difficult to misuse. You'll **make your objects' data private**, and add **properties** to protect how that data is accessed—and you'll keep your objects' important data from **leaking out to other objects** so they don't accidentally misuse it.



Let's help Owen roll for damage	272
Create a console app to calculate damage	273
Design a MAUI version of the damage calculator app	275
Use Debug.WriteLine to print diagnostic information	281
Use encapsulation to control access to your class's methods and fields	286
Private fields and methods can only be accessed from instances of the same class	288
Why encapsulation? Think of an object as an opaque box...	293
Let's use encapsulation to improve the SwordDamage class	297
Write a console app to test the PaintballGun class	299
Auto-implemented properties simplify your code	302
Use a private setter to create a read-only property	303
Use a constructor with parameters to initialize properties	305
Specify arguments when you use the new keyword	306
Initialize fields and properties inline or in the constructor	313

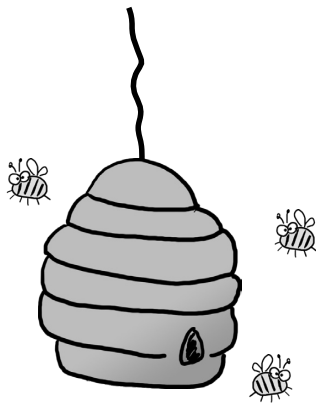


inheritance

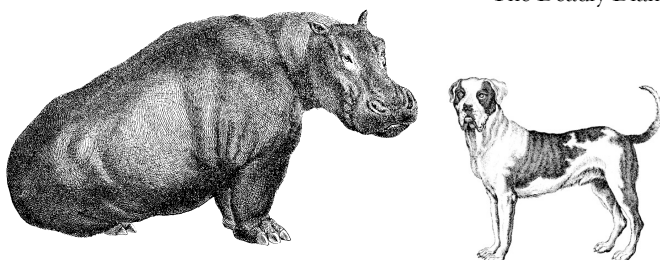
Your object's family tree**6****Sometimes you DO want to be just like your parents.**

Ever run across a class that *almost* does exactly what you want *your* class to do?

Found yourself thinking that if you could just *change a few things*, that class would be perfect? With **inheritance**, you can **extend** an existing class so your new class gets all of its behavior—with the **flexibility** to make changes to that behavior so you can tailor it however you want. Inheritance is one of the most powerful concepts and techniques in the C# language: with it, you can **avoid duplicate code**, **model the real world** more closely, and end up with apps that are **easier to maintain** and **less prone to bugs**.



Use a switch statement to match several candidates	327
When your classes use inheritance, you only need to write your code once	330
How would you design a zoo simulator?	332
Any place where you can use a base class, you can use one of its subclasses instead	338
A subclass can override methods to change or replace members it inherited	344
Build an app to explore virtual and override	352
A subclass can hide methods in the base class	354
Use the override and virtual keywords to inherit behavior	356
A class should do one thing	366
Build a Beehive Management System	370
Feedback drives your beehive management game	388
The Beehive Management System is turn-based... now let's convert it to real-time	390
An abstract class is an intentionally incomplete class	394
Abstract properties work just like abstract methods	398
The Deadly Diamond of Death	401

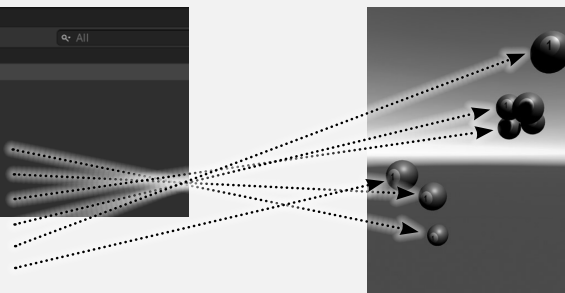
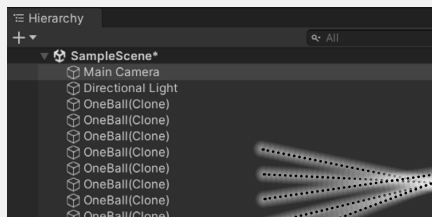


Unity Lab 3

GameObject Instances

C# is an object-oriented language, and since these Head First C# Unity Labs are all **about getting practice writing C# code**, it makes sense that these labs will focus on creating objects.

Let's build a game in Unity!	404
Create a new material inside the Materials folder	405
Spawn a billiard ball at a random point in the scene	406
Use the debugger to understand Random.value	407
Turn your GameObject into a prefab	408
Create a script to control the game	409
Attach the GameController script to the Main Camera	410
Press Play to run your code	411
Use the Inspector to work with GameObject instances	412
Use physics to keep balls from overlapping	413
Get creative!	414



interfaces, casting, and is

7

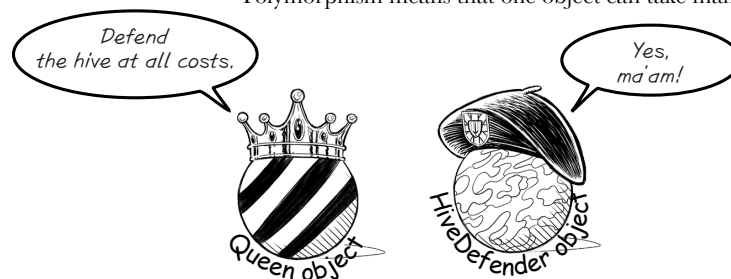
Making classes keep their promises

Need an object to do a specific job? Use an interface.

Sometimes you need to group your objects together based on the things they can do rather than the classes they inherit from—and that's where interfaces come in. You can use an interface to define a **specific job**. Any instance of a class that **implements** the interface is *guaranteed to do that job*, no matter what other classes it's related to. To make it all work, any class that implements an interface must promise to fulfill all of its obligations...or the compiler will break its kneecaps, see?



The beehive is under attack!	416
We could use casting to call the DefendHive method...	417
An interface defines methods and properties that a class must implement...	418
Interfaces let unrelated classes do the same job	419
Get a little practice using interfaces	420
You can't instantiate an interface, but you can reference an interface	426
Interface references are ordinary object references	429
The RoboBee 4000 can do a worker bee's job without using valuable honey	430
What if we want different animals to swim or hunt in packs?	438
Use interfaces to work with classes that do the same job	439
Safely navigate your class hierarchy with is	440
C# has another tool for safe type conversion: the as keyword	441
Use upcasting and downcasting to move up and down a class hierarchy	442
Upcasting and downcasting work with interfaces too	446
Default implementations give bodies to interface methods	456
Data binding updates MAUI controls automatically	459
Polymorphism means that one object can take many different forms	469



enums and collections

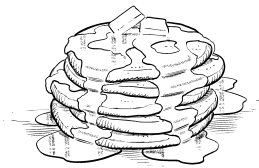
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Organizing your data

Data isn't always as neat and tidy as you'd like it to be.

In the real world, you don't receive your data in tidy little bits and pieces. No, your data's going to come at you in loads, piles, and bunches. You'll need some pretty powerful tools to organize all of it—and lucky for us, C# has just the tools we need. **Enums** are types that let you define valid values to categorize your data. **Collections** are special objects that store many values, letting you **store, sort, and manage** all the data that your apps need to pore through. That way, you can spend your time thinking about writing apps to work with your data, and let the collections worry about keeping track of it for you.

The rarely played Duke of Oxen card.



If a constructor just sets fields, use a primary constructor instead	474
A primary constructor can extend a base constructor	475
Enums let you work with a set of valid values	477
Enums let you represent numbers with names	478
Lists make it easy to store collections of...anything	483
Let's build an app to store shoes	487
Generic collections can store any type	490
You can use collection expressions to create Lists	496
IComparable<Duck> helps your List sort its Ducks	499
Create an instance of your comparer object	501
Comparers can do complex comparisons	502
You can upcast an entire list using IEnumerable<T>	510
The Dictionary functionality rundown	513
CollectionView is a MAUI control built for displaying collections	524
ObservableCollection is a collection made for data binding	525
Use XAML to instantiate your objects for data binding	529
Modify your app to use a resource Dictionary	530
Modify the event handlers to use the resource Dictionary	532
Use what you've learned to build an app with two decks	533

Sorted by kind of duck... →

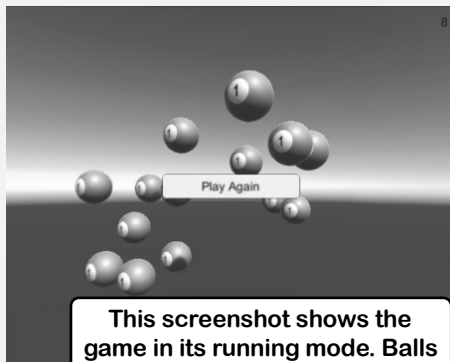


Unity Lab 4

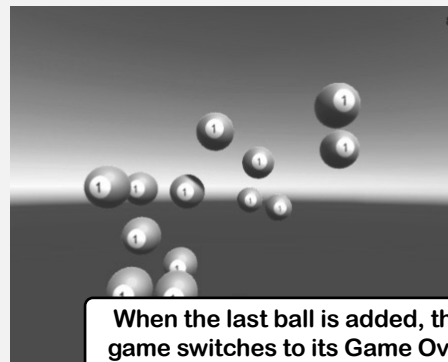
User Interfaces

In the last Unity Lab you started to build a game, using a prefab to create `GameObject` instances that appear at random points in 3D space and fly in circles. This Unity Lab picks up where the last one left off, allowing you to apply what you've learned about interfaces in C# and more.

Add a score that goes up when the player clicks a ball	540
Add two different modes to your game	541
Add game mode to your game	542
Add a UI to your game	544
Set up the Text that will display the score in the UI	545
Add a button that calls a method to start the game	546
Make the Play Again button and Score Text work	547
Finish the code for the game	548
Get creative!	552



This screenshot shows the game in its running mode. Balls are added and the player can click on them to score.



When the last ball is added, the game switches to its Game Over mode. The Play Again button pops up and no more balls get added.

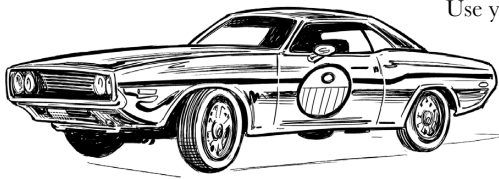
LINQ and lambdas

Get control of your data

9

It's a data-driven world...we all need to know how to live in it.

Gone are the days when you could program for days, even weeks, without dealing with **loads of data**. Today, **everything is about data**, and that's where **LINQ** comes in. LINQ is a feature of C# and .NET that not only lets you **query data** in your .NET collections in an intuitive way, but lets you **group data** and **merge data from different data sources**. You'll use **anonymous objects** to manage your data in new and interesting ways. You'll add **unit tests** to make sure your code is working the way you want. Once you've got the hang of wrangling your data into manageable chunks, you can use **lambda expressions** to refactor your C# code to make it easier to work with and more expressive.



Jimmy's a Captain Amazing super-fan...	554
Use LINQ to query your collections	556
Use a LINQ query to finish the app for Jimmy	564
The var keyword lets C# figure out variable types for you	566
LINQ is versatile	572
Use a group query to separate your sequence into groups	574
Use join queries to merge data from two sequences	577
Use the new keyword to create anonymous types	578
Unit tests help you make sure your code works	587
Start writing your first test method	588
One project can only access public classes in another project	590
Use the Arrange-Act-Assert pattern to write an effective test	591
Write a unit test for the GetReviews method	594
Use the => operator to create lambda expressions	598
Use the ?: operator to make your lambdas make choices	603
LINQ queries are made up of methods	604
LINQ declarative syntax can be refactored into chained methods	606
Use the => operator to create switch expressions	609
Explore the Enumerable class	613
Use yield return to create your own sequences	615

reading and writing files

Save the last byte for me

10

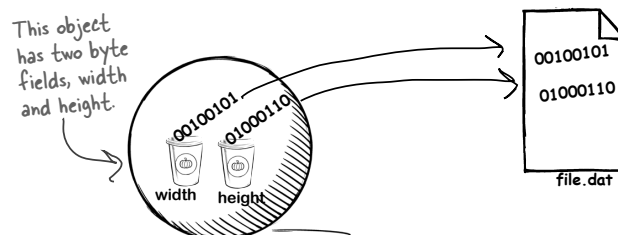
Sometimes it pays to be persistent.

So far, all of your programs have been pretty short-lived. They fire up, run for a while, and shut down. But that's not always enough, especially when you're dealing with important information. You need to be able to **save your work**. In this chapter, we'll look at how to **write data to a file**, and then how to **read that information back in** from a file. You'll learn about **streams**, and how to store your objects in files with **serialization**, and get down to the actual bits and bytes of **hexadecimal**, **Unicode**, and **binary data**.



```
0000: 45 6c 65 6d 65 6e 74 61 Elementa
0005: 72 79 2c 20 6d 79 20 64 ry, my d
0010: 65 61 72 20 57 61 74 73 ear Wats
0015: 6f 6e 21 on!
```

.NET uses streams to read and write data	622
Different streams read and write different things	623
Use a StreamReader to read a file	629
Use the static File and Directory classes to work with files and directories	634
IDisposable makes sure objects are closed properly	637
Avoid filesystem errors with using statements	638
Use a MemoryStream to stream data to memory	639
What happens to an object when it's serialized?	645
Use JsonSerializer to serialize your objects	648
JSON only includes data, not specific C# types	651
C# strings are encoded with Unicode	655
.NET uses Unicode to store characters and text	658
C# can use byte arrays to move data around	660
Use a BinaryWriter to write binary data	661
Use BinaryReader to read the data back in	662
Use StreamReader to build a hex dumper	665
Use Stream.Read to read bytes from a stream	666
Modify your hex dumper to read directly from the stream	667
Run your app from the command line	668

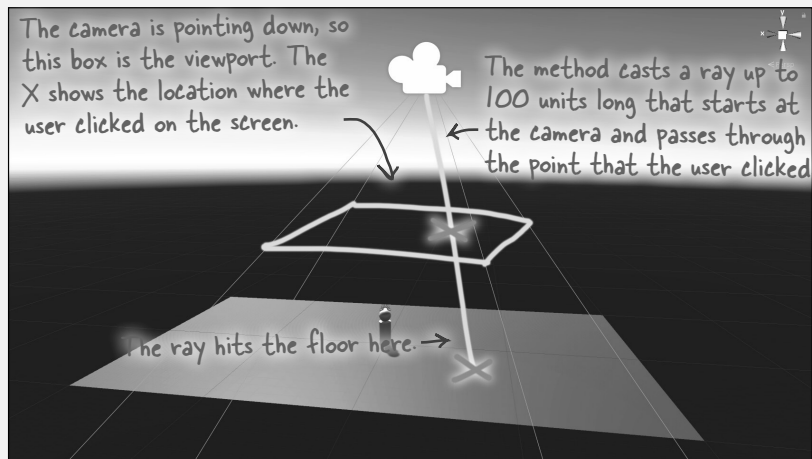


Unity Lab 5

Raycasting

When you set up a scene in Unity, you're creating a virtual 3D world for the characters in your game to move around in. But in most games, things aren't directly controlled by the player. So how do these objects find their way around a scene? In this lab, we'll look at how C# can help.

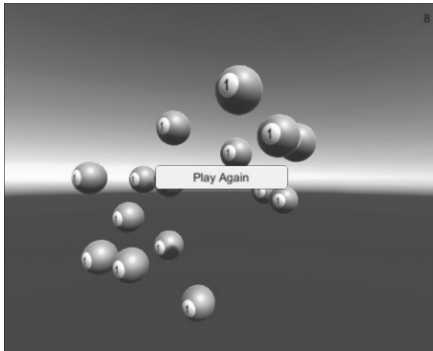
Create a new Unity project and start to set up the scene	674
Set up the camera	675
Create a GameObject for the player	676
Introducing Unity's navigation system	677
Install the AI Navigation package	678
Things you'll do with navigation	679
Set up the NavMesh	680
Make your player automatically navigate the play area	683



CAPTAIN AMAZING

THE DEATH OF THE OBJECT

Head First C#	
Four bucks	Chapter 11



The life and death of an object	690
Use the GC class (with caution) to force garbage collection	691
Your last chance to DO something... your object's finalizer	692
When EXACTLY does a finalizer run?	693
Finalizers can't depend on other objects	695
A struct looks like an object...	699
Values get copied; references get assigned	700
Structs are value types; objects are reference types	701
The stack versus the heap: more on memory	703
Use out parameters to make a method return more than one value	706
Pass by reference using the ref modifier	707
Use optional parameters to set default values	708
A null reference doesn't refer to any object	709
Non-nullable reference types help you avoid NREs	710
Nullable value types can be null...and handled safely	713
The null-coalescing operator ?? checks for nulls automatically	714
"Captain" Amazing...not so much	715
Records give your objects value equality automatically	717
Don't modify records—copy them	718
Extension methods add new behavior to EXISTING classes	723
Extending a fundamental type: string	724

*Just...need to do...
- gasp -
one...last...thing...*

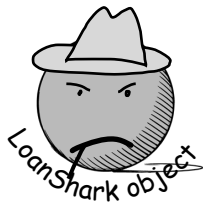
exception handling

Putting out fires gets old

12

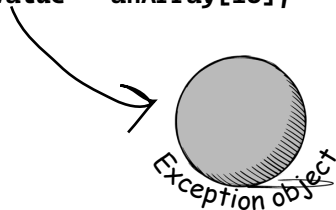
When you have to deal with error after error, it's called "putting out fires."

Imagine: it's a few years from now. You spent all that time working on your C# skills and continuing to learn and improve, and now you're one of the most senior developers at a big tech company. Now you're getting panicked phone calls in the middle of the night from your support team because **your app crashes**, or **doesn't behave like it's supposed to**. You want to spend your time writing code, not putting out fires! Because nothing pulls you out of the programming groove like having to fix a strange bug you don't recognize. Luckily, C# has **exception handling**, which lets you write code to **deal with problems** that come up. Better yet, you can even plan for those problems, and **keep things running** when they happen.



Your hex dumper reads a filename from the command line	732
When your program throws an exception, the CLR generates an Exception object	736
All Exception objects inherit from System.Exception	737
There are some files you just can't dump	740
What happens when a method you want to call is risky?	741
Handle exceptions with try and catch	742
Use the debugger to follow the try/catch flow	743
Catch-all exceptions handle System.Exception	745
Use the right exception for the situation	750
Exception filters help you create precise handlers	754
The worst catch block EVER: catch-all plus comments	756
Temporary solutions are OK (temporarily)	757
Use NuGet to add a logging library to your app	759
Add logging to your ExceptionExperiment app	760

```
int[] anArray = {3, 4, 1, 11};
int aValue = anArray[15];
```

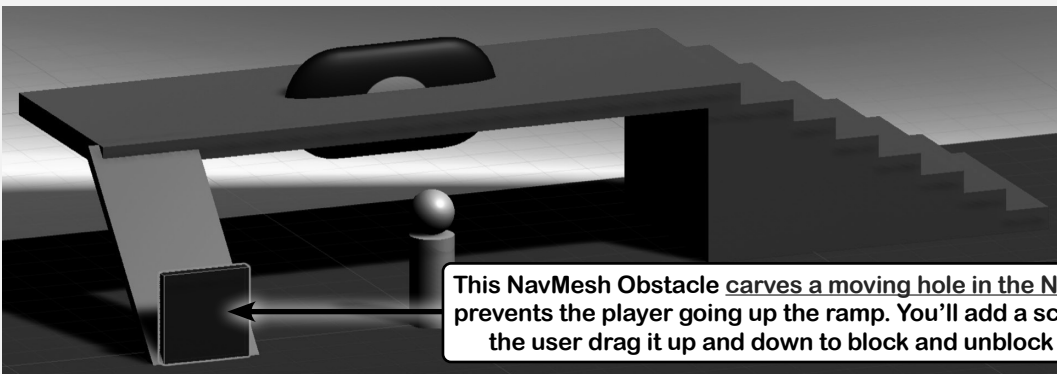


Unity Lab 6

Scene Navigation

In the last Unity Lab, you created a scene with a floor (a plane) and a player (a sphere nested under a cylinder), and you used a NavMesh, a NavMesh Agent, and raycasting to get your player to follow your mouse clicks around the scene. In this lab, you'll add to the scene with the help of C#.

Let's pick up where the last Unity Lab left off	764
Add a platform to your scene	765
Use bake options to make the platform walkable	766
Include the stairs and ramp in the NavMesh	767
Make the player navigate around the obstacles	769
Get creative!	770



Are you ready?

how to use this book

Intro



In this section, we answer the burning question:
“So why DID they put that in a book on learning C#?”

Who is this book for?

If you can answer “yes” to all of these:

- 1 Do you want to **learn C#** (and pick up some knowledge of game development and Unity along the way)?
- 2 Do you like to tinker? Do you learn by doing, rather than just reading?
- 3 Do you prefer **interesting and stimulating conversation** to **dry, dull, academic lectures**?

This book is for you.



Who should probably back away from this book?

If you can answer “yes” to any of these:

- 1 Are you more interested in theory than practice?
- 2 Does the idea of doing projects and writing code make you bored and a little twitchy?
- 3 Are you **afraid to try something different**? Do you think a book about a serious topic like development needs to be serious all the time?

you might consider trying another book first.



Do I need to know another programming language to use this book?



A lot of people learn C# as a second (or third, or sixteenth) language, but you don't need to have written a lot of code to get started.

If you've written programs (even small ones!) in *any* programming language, taken an introductory programming class at school or online, done some scripting, used a database query language, done some web page design, or worked with Excel functions, then you've **definitely** got the background for this book, and you'll feel right at home.

What if you have less experience? That's OK! You can go at your own pace, which is why thousands of beginners have used our book to learn C# as their first programming language.

Still not sure if this book is right for you? Try doing the first few chapters—you can download a free PDF of the first four chapters from <https://github.com/head-first-csharp/fifth-edition>. If you're still comfortable after doing all of the exercises, then this book will work well for you.

We know what you're thinking

“How can *this* be a serious C# programming book?”

“What’s with all the graphics?”

“Can I actually *learn* it this way?”

We know what your *brain* is thinking

Your brain craves novelty. It’s always searching, scanning, *waiting* for something unusual. It was built that way, and it helps you stay alive.

So what does your brain do with all the routine, ordinary, normal things you encounter? Everything it *can* to stop them from interfering with the brain’s *real* job—recording things that *matter*. It doesn’t bother saving the boring things; they never make it past the “this is obviously not important” filter.

How does your brain *know* what’s important? Suppose you’re out for a day hike and a tiger jumps out in front of you. What happens inside your head and body?

Neurons fire. Emotions crank up. *Chemicals surge.*

And that’s how your brain knows...

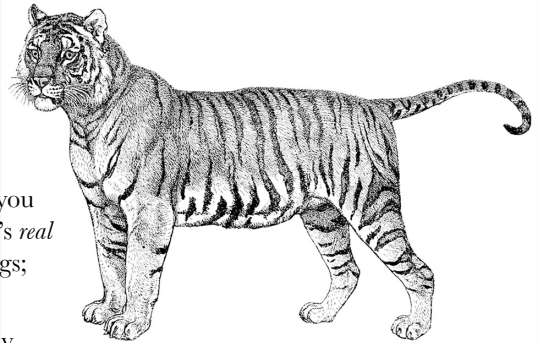
This must be important! Don’t forget it!

But imagine you’re at home, or in a library. It’s a safe, warm, tiger-free zone. You’re studying. Getting ready for an exam. Or trying to learn some tough technical topic your boss thinks will take a week, 10 days at the most.

Just one problem. Your brain’s trying to do you a big favor. It’s trying to make sure that this *obviously* unimportant content doesn’t clutter up scarce resources. Resources that are better spent storing the really *big* things. Like tigers. Like the danger of fire. Like how you should never have posted those “party” photos on your Facebook page.

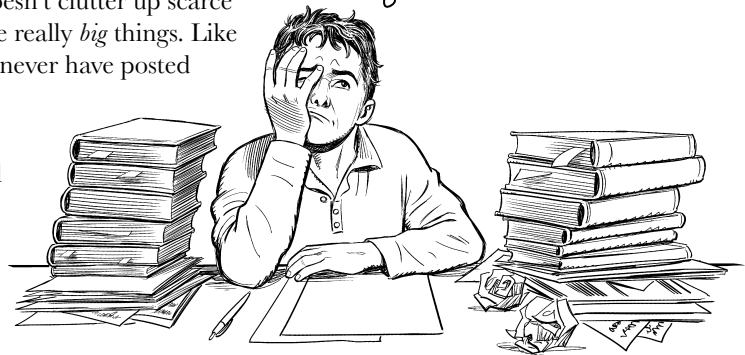
And there’s no simple way to tell your brain, “Hey brain, thank you very much, but no matter how dull this book is, and how little I’m registering on the emotional Richter scale right now, I really *do* want you to keep this stuff around.”

Your brain thinks
THIS is important.



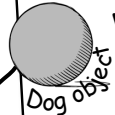
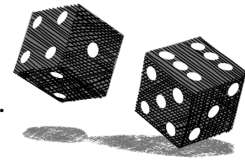
Your brain thinks
THIS isn't worth
saving.

Great. Only 800
more dull, dry,
boring pages.



We think of a “Head First” reader as a learner.

So what does it take to *learn* something? First you have to *get* it, then make sure you don’t *forget* it. It’s not about pushing facts into your head. Based on the latest research in cognitive science, neurobiology, and educational psychology, *learning* takes a lot more than text on a page. We know what turns your brain on.



Some of the Head First learning principles:

Make it visual. Images are far more memorable than words alone, and make learning much more effective (up to 89% improvement in recall and transfer studies). They also make things more understandable.

Put the words within or near the graphics they relate to, rather than at the bottom or on another page, and learners will be up to *twice* as likely to be able to solve problems related to the content.

Use a conversational and personalized style. In recent studies, students performed up to 40% better on postlearning tests if the content spoke directly to the reader, using a first-person, conversational style rather than taking a formal tone. Tell stories instead of lecturing. Use casual language. Don’t take yourself too seriously. Which would *you* pay more attention to: a stimulating dinner party companion, or a lecture?

Get the learner to think more deeply. Unless you actively flex your neurons, nothing much happens in your head. A reader has to be motivated, engaged, curious, and inspired to solve problems, draw conclusions, and generate new knowledge. And for that, you need challenges, exercises, and thought-provoking questions, and activities that involve both sides of the brain and multiple senses.

Get—and keep—the reader’s attention. We’ve all had the “I really want to learn this but I can’t stay awake past page one” experience. Your brain pays attention to things that are out of the ordinary, interesting, strange, eye-catching, unexpected. Learning a new, tough, technical topic doesn’t have to be boring. Your brain will learn much more quickly if it’s not.

Touch their emotions. We now know that your ability to remember something is largely dependent on its emotional content. You remember what you care about. You remember when you *feel* something. No, we’re not talking heart-wrenching stories about a boy and his dog. We’re talking emotions like surprise, curiosity, fun, “what the...?” and the amazing “Aha! I got this!” feeling that comes when you solve a puzzle, learn something everybody else thinks is hard—or maybe just realize you’ve learned so much *great new stuff* and it feels so good to be able to use it.



Even scary emotions can help ideas stick in your brain.



Metacognition: thinking about thinking

If you really want to learn, and you want to learn more quickly and more deeply, pay attention to how you pay attention. Think about how you think. Learn how you learn.

Most of us did not take courses on metacognition or learning theory when we were growing up. We were *expected* to learn, but rarely *taught* to learn.

But we assume that if you're holding this book, you really want to learn how to build programs in C#. And you probably don't want to spend a lot of time on it. If you want to use what you read in this book, you need to *remember* what you read. And for that, you've got to *understand* it. To get the most from this book, or *any* book or learning experience, take responsibility for your brain. Your brain on *this* content.

The trick is to get your brain to see the new material you're learning as Really Important. Crucial to your well-being. As important as a tiger. Otherwise, you're in for a constant battle, with your brain doing its best to keep the new content from sticking.

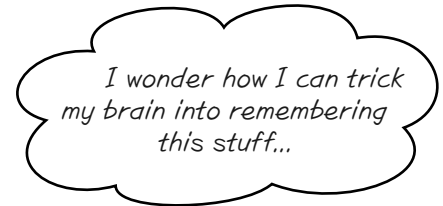
So just how **DO** you get your brain to treat C# like it was a hungry tiger?

There's the slow, tedious way, or the faster, more effective way. The slow way is about sheer repetition. You obviously know that you *are* able to learn and remember even the dullest of topics if you keep pounding the same thing into your brain. With enough repetition, your brain says, "This doesn't *feel* important, but they keep looking at the same thing *over* and *over* and *over*, so I suppose it must be."

The faster way is to do **anything that increases brain activity**, especially different *types* of brain activity. The things on the previous page are a big part of the solution, and they're all things that have been proven to help your brain work in your favor. For example, studies show that putting words *within* the pictures they describe (as opposed to somewhere else on the page, like in a caption or in the body text) causes your brain to try to make sense of how the words and pictures relate, and this causes more neurons to fire. More neurons firing = more chances for your brain to *get* that this is something worth paying attention to, and possibly recording.

A conversational style helps because people tend to pay more attention when they perceive that they're in a conversation, since they're expected to follow along and hold up their end. The amazing thing is, your brain doesn't necessarily *care* that the "conversation" is between you and a book! On the other hand, if the writing style is formal and dry, your brain perceives it the same way you experience being lectured to while sitting in a roomful of passive attendees. No need to stay awake.

But pictures and conversational style are just the beginning.



Here's what WE did:

We used **pictures**, because your brain is tuned for visuals, not text. As far as your brain's concerned, a picture really *is* worth a thousand words. And when text and pictures work together, we embedded the text *in* the pictures because your brain works more effectively when the text is *within* the thing the text refers to, as opposed to in a caption or buried in the text somewhere.

We used **redundancy**, saying the same thing in *different* ways and with different media types, and *multiple senses*, to increase the chance that the content gets coded into more than one area of your brain.

We used concepts and pictures in **unexpected** ways because your brain is tuned for novelty, and we used pictures and ideas with at least *some emotional content*, because your brain is tuned to pay attention to the biochemistry of emotions. That which causes you to *feel* something is more likely to be remembered, even if that feeling is nothing more than a little **humor, surprise, or interest**.

We used a personalized, **conversational style**, because your brain is tuned to pay more attention when it believes you're in a conversation than if it thinks you're passively listening to a presentation. Your brain does this even when you're *reading*.

We included dozens of **activities**, because your brain is tuned to learn and remember more when you **do** things than when you *read* about things. And we made the paper puzzles and code exercises challenging yet doable, because that's what most people prefer.

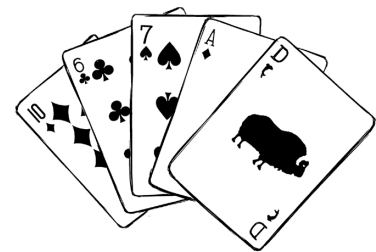
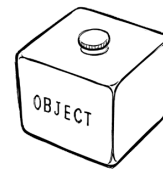
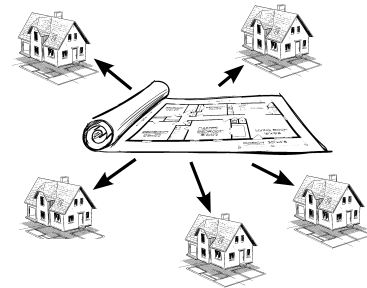
We used **multiple learning styles**, because *you* might prefer step-by-step procedures, while someone else wants to understand the big picture first, and someone else just wants to see an example. But regardless of your own learning preference, *everyone* benefits from seeing the same content represented in multiple ways.

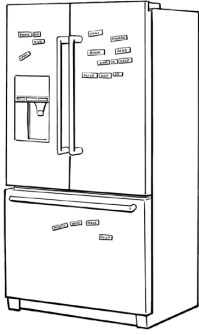
We included content for **both sides of your brain**, because the more of your brain you engage, the more likely you are to learn and remember, and the longer you can stay focused. Since working one side of the brain often means giving the other side a chance to rest, you can be more productive at learning for a longer period of time.

And we included **stories** and exercises that present **more than one point of view**, because your brain is tuned to learn more deeply when it's forced to make evaluations and judgments.

We included **challenges**, with exercises, and asked **questions** that don't always have a straight answer, because your brain is tuned to learn and remember when it has to *work* at something. Think about it—you can't get your *body* in shape just by *watching* people at the gym. But we did our best to make sure that when you're working hard, it's on the *right* things. That **you're not spending one extra dendrite** processing a hard-to-understand example, or parsing difficult, jargon-laden, or overly terse text.

We used **people**. In stories, examples, pictures, etc., because, well, because *you're* a person. And your brain pays more attention to *people* than it does to *things*.





Here's what YOU can do to bend your brain into submission

So, we did our part. The rest is up to you. These tips are a starting point; listen to your brain and figure out what works for you and what doesn't. Try new things.

Cut this out and stick it on your refrigerator.

1 Slow down. The more you understand, the less you have to memorize.

Don't just *read*. Stop and think. When the book asks you a question, don't just skip to the answer. Imagine that someone really *is* asking the question. The more deeply you force your brain to think, the better chance you have of learning and remembering.

2 Do the exercises. Write your own notes.

We put them in, but if we did them for you, that would be like having someone else do your workouts for you. And don't just *look* at the exercises. **Use a pencil.** There's plenty of evidence that physical activity *while* learning can increase the learning.

3 Read the "There are no Dumb Questions" sections.

That means all of them. They're not optional sidebars—***they're part of the core content!*** Don't skip them.

4 Make this the last thing you read before bed. Or at least the last challenging thing.

Part of the learning (especially the transfer to long-term memory) happens *after* you put the book down. Your brain needs time on its own, to do more processing. If you put in something new during that processing time, some of what you just learned will be lost.

5 Drink water. Lots of it.

Your brain works best in a nice bath of fluid. Dehydration (which can happen before you ever feel thirsty) decreases cognitive function.

6 Talk about it. Out loud.

Speaking activates a different part of the brain. If you're trying to understand something, or increase your chance of remembering it later, say it out loud. Better still, try to explain it out loud to someone else. You'll learn more quickly, and you might uncover ideas you hadn't known were there when you were reading about it.

7 Listen to your brain.

Pay attention to whether your brain is getting overloaded. If you find yourself starting to skim the surface or forget what you just read, it's time for a break. Once you go past a certain point, you won't learn faster by trying to shove more in, and you might even hurt the process.

8 Feel something.

Your brain needs to know that this *matters*. Get involved with the stories. Make up your own captions for the photos. Groaning over a bad joke is *still* better than feeling nothing at all.

9 Write a lot of code!

There's only one way to *really* learn C# so it sticks: **write a lot of code.** And that's what you're going to do throughout this book. Coding is a skill, and the only way to get good at it is to practice. We're going to give you a lot of practice: every chapter has exercises that pose a problem for you to solve. Don't just skip over them—a lot of the learning happens when you solve the exercises. If you get stuck, don't be afraid to **peek at the solution!** We included a solution to each exercise for a reason: it's easy to get snagged on something small. But try to solve the problem before you look at the solution. And definitely get it working before you move on to the next part of the book.

README.md

This is a learning experience, not a reference book. We deliberately stripped out everything that might get in the way of learning whatever it is we're working on at that point in the book. And the first time through, you need to begin at the beginning, because the book makes assumptions about what you've already seen and learned.

The activities are NOT optional.

The puzzles and activities are not add-ons; they're part of the core content of the book. Some of them are to help with memory, some for understanding, and some to help you apply what you've learned. ***Don't skip the written problems.*** The pool puzzles are the only things you don't *have* to do, but they're good for giving your brain a chance to think about twisty little logic puzzles—and they're definitely a great way to really speed up the learning process.

The redundancy is intentional and important.

One distinct difference in a Head First book is that we want you to *really* get it. And we want you to finish the book remembering what you've learned. Most reference books don't have retention and recall as a goal, but this book is about *learning*, so you'll see some of the same concepts come up more than once.

Do all the exercises!

The one big assumption that we made when we wrote this book is that you want to learn how to program in C#. So we know you want to get your hands dirty right away, and dig right into the code. We gave you a lot of opportunities to sharpen your skills by putting exercises in every chapter. We've labeled some of them “**Do this!**”—when you see that, it means that we'll walk you through all of the steps to solve a particular problem. But when you see the Exercise logo with the running shoes, then we've left a big portion of the problem up to you to solve, and we gave you the solution that we came up with. Don't be afraid to peek at the solution—**it's not cheating!** But you'll learn the most if you try to solve the problem first.

We've also included all the exercise solutions' source code with the rest of the code from this book.

You can find all of it on our GitHub page: <https://github.com/head-first-csharp/fifth-edition>

The “Brain Power” questions don't have answers.

For some of them, there is no right answer, and for others, part of the learning experience is for you to decide if and when your answers are right. In some of the Brain Power questions you will find hints to point you in the right direction.

We're targeting C# 12, Visual Studio 2022, and Visual Studio Code.

This book is all about helping you learn C#. The team at Microsoft that develops and maintains C# releases updates to the language. **C# 12** is the current version at the time this book is going into production. We also lean very heavily on Visual Studio, Microsoft's integrated development environment (IDE), as a tool for learning, teaching, and exploring C#. The screenshots in this book were taken with the **latest versions of Visual Studio 2022 and Visual Studio Code** available at the time of production. We included instructions for installing Visual Studio and Visual Studio Code in Chapter 1.

C# is constantly evolving, and new versions will have great new features! But don't worry—the features of C# that are part of the core learning in this book will be unchanged, so you will be able to use this book with future versions of C#. The Microsoft teams that maintain Visual Studio and Visual Studio for Mac routinely release updates, and very rarely those changes will affect screenshots in this book.

The Unity Lab sections in this book target **Unity 6**, the latest version of Unity available with long-term support when this book went into production. We included instructions for installing Unity in the first Unity Lab.

You can watch **full video walkthroughs** of Visual Studio, Visual Studio Code, and Unity installation on our YouTube channel: <https://www.youtube.com/@headfirstcsharp>

All of the code in this book is released under an open source license that lets you use it for your own projects. You can download it from our GitHub page (<https://github.com/head-first-csharp/fifth-edition>).



Game Design...and Beyond

How we use games in this book

You're going to be writing code for lots of projects throughout this book, and many of those projects are games. We didn't do this just because we love games. Games can be **effective tools for learning and teaching C#**. Here's why:

- Games are **familiar**. You're about to immerse yourself in a lot of new concepts and ideas. Giving you something familiar to grab onto can make the learning process go more smoothly.
- Games make it easier to **explain projects**. When you do any of the projects in this book, the first thing you need to do is understand what we're asking you to build—and that can be surprisingly difficult. When we use games for our projects, that makes it easier for you to quickly figure out what we're asking and dive right into the code.
- Games are **fun to write!** Your brain is much more receptive to new information when you're having fun, so including coding projects where you'll build games is, well, a no-brainer (excuse the pun).

We use games throughout this book to help you learn broader C# and programming concepts. They're an important part of the book. You should do all of the game-related projects in the book, even if you're not interested in game development. (The Unity Labs are optional, but strongly recommended.)

The technical review team

Charlotte M. Ellett

Photo credit: Ryan Lash/TED



Layla Porter



Gerald Versluis



“If I have seen further, it is by standing on the shoulders of giants.”

—Isaac Newton

The book you’re reading has very few errors in it, and we give a TON of credit for its high quality to our amazing team of technical reviewers—the giants who kindly lent us their shoulders.

To the review team: we’re so incredibly grateful for the work that you all did for this book. Thank you so much!

Charlotte M. Ellett is a game developer and programmer, electronics enthusiast and maker, and has been a TED Resident, Red Hat developer relations expert, and Space Camp Crew Trainer. She enjoys making DIY projects and conducting experiments with (not on) her family, and teaching the next generation of engineers and scientists. You can find her at *CharlotteMEllett.com*.

Layla Porter is an experienced software engineer and developer advocate specialising in .NET technologies. Layla has been awarded the Microsoft MVP award for the past five years and the GitHub Star award for the past three. She has spoken at developer conferences all over Europe and North America and is a YouTube content creator. She enjoys hiking, reading urban fantasy novels, playing video games with her husband, and doting on her two miniature pinschers, Cookie and Lily.

↪ Layla actually used the third edition of this book to learn C# in 2015 before applying for her first developer job!

Gerald Versluis is a senior software engineer at Microsoft on the .NET MAUI team. Besides his day job he is also passionate about sharing his knowledge and learning with others. Gerald regularly speaks at conferences, writes blogs and articles, post videos on his YouTube channel, and contributes to open source projects. You can find Gerald on every major social media platform under @jfversluis or on his website: <https://jfversluis.dev>

We also want to give special thanks to **Joe Albahari** and **Jon Skeet** for their incredible technical guidance and really careful and thoughtful review of the first edition, which truly set us up for the success we’ve had with this book over the years. We benefited so much from your input—even more, in fact, than we realized at the time.

“Shoulders of giants”

This is the **fifth edition** of *Head First C#*, which means a lot of what you’ll read in this book was also in an earlier edition. Some of it even dates back to the very first edition from 2008! So it’s important to us that we acknowledge the amazing contributions of our **fourth edition tech review team**:



← Lisa was also on the team for the third, second, and first editions. Thank you!

And our **third edition tech review team**:



Chris Burrows



And our **second edition team**:

David Sterling

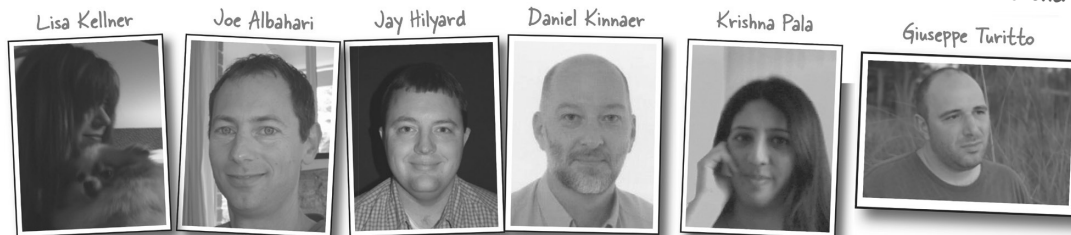


Nick Paladino



And finally, our **first edition team**:

Chris and David helped us with both the third and second editions. Thank you!



Folks from the first edition team who aren’t pictured, but just as amazing: Wayne Bradney, Dave Murdoch, and especially Bridgette Julie Landers.

And super special thanks to our wonderful readers—especially Alan Ouellette, Jeff Counts, Terry Graham, Sergei Kulagin, William Piva, Jim Cupec, Mike Olgren, David Horvitz, and Greg Combow—who let us know about issues they found while reading our book, and professor Joe Varrasso at Mohawk College for being an early adopter of our book for his course.

Thank you all so much!!

Acknowledgments

Our editor:

First and foremost, we want to thank our amazing editor, **Michele Cronin**, for everything you've done for this book. It was such a pleasure working with you!

These people are amazing and it's been such a privilege working with them. Thank you all!



Michele Cronin



The O'Reilly team:

Katherine Tozer



There are so many people at O'Reilly we want to thank that we hope we don't forget anyone! First, last, and always, we want to thank **Mary Treseler**, who's been with us on our journey with O'Reilly from the very beginning. Special thanks to production editor **Katherine Tozer**, indexer **Joanne Sprott**, and **Elizabeth Oliver** for her sharp proofread—all of whom helped get this book from production to press in record time. A huge and heartfelt thanks to **Amanda Quinn**, **Zan McQuade**, **Olivia MacDonald**, **Melissa Duffield**, and **Brian Guerin** for getting this project on track from the beginning, and being so supportive of our books and training courses over the years. And a big shout-out to our other friends at O'Reilly: **Mike Hendrickson**, **Lindsay Ventimiglia**, **David Michelson**, **Jeff Bleiel**, and, of course, **Tim O'Reilly**. If you're reading this book right now, then you can thank the best publicity team in the industry: **Marsee Henon**, **Kathryn Barrett**, and the rest of the wonderful folks at Sebastopol.

We also want to give a shout-out to some of our favorite O'Reilly authors:

- **Dr. Paris Buttfield-Addison**, **Jon Manning**, and **Tim Nugent**, whose book *Unity Game Development Cookbook* is just simply amazing, and whose other O'Reilly books, including *Head First Swift*, are also fantastic.
- **Joseph Albahari**, who wrote the thoroughly indispensable *C# 12 in a Nutshell*.
- **David Pine**, whose *Learning Blazor: Build Single-Page Apps with WebAssembly and C#* is perfect for anyone who wants to build modern web apps in C#.

...and a few more folks who have been so incredibly supportive over the years

Thank you so much to **Cathy Vice** for her amazing piece on epilepsy that we used in Chapter 10, and for all her epilepsy advocacy work. Thank you to **Jesse Liberty** for some great advice and all of his books over the years. And we really, really want to thank **Jeremy Sinclair** for his advice on characters, and for being a pillar of the .NET community.

And an *enormous thank you to our friends at Microsoft* who helped us so much with this book—your support through this project was amazing. Thank you so much to **Maddy Montaquila**, **Shane Neville**, and **Gerald Versluis** from the MAUI team—especially Shane's feedback on our code and Gerald's unbelievably valuable tech review. We're grateful for **Jen Gentleman** for teaching us about some great Windows features (like the emoji panel!)

We're also so grateful to **Dominic Nahous**, **Jordan Matthiesen**, and **John Miller** from the Visual Studio for Mac team, and to **Cody Beyer**, who was instrumental in getting our whole partnership with that team started. Thank you to **David Sterling** for an awesome review of previous editions, and **Immo Landwerth** for helping us nail down topics we should cover in the fourth edition. *Extra special thanks* to **Mads Torgersen**, program manager for the C# language, for all the wonderful guidance and advice he's given us over the years. You all are fantastic!

And finally, we're especially grateful to **Jon Galloway**, who provided so much amazing code for the Blazor projects in the Blazor downloadable PDF—collaborating with you was a truly wonderful experience. Thank you so much!

1 start building apps with C#

Build something great...fast!



Want to build great apps...right now?

With C#, you've got a modern programming language and a **valuable tool** at your fingertips. And with **Visual Studio**, you've got an amazing development environment with highly intuitive features that make coding as easy as possible. Not only is Visual Studio a great tool for writing code, it's also a **really effective learning tool** for exploring C#. Sound appealing? ***Let's get coding!***

Learn C#...and learn to become a great developer

Do you want to become a great developer? Yes? Then you came to the right book! You **can** become a great developer, and **C# is the perfect language** to help you get there. Here's why:

- ★ **C# is a powerful, modern language** that lets you do incredible things. You can use it to build everything from games to websites to serious business applications. You name it, C# can do it.
- ★ **C# skills are in demand.** Are you looking to land a programming job? C# is one of the most in-demand programming languages around because companies all over the world use C# to build their desktop applications and websites.
- ★ **C# is cross-platform.** You can write apps that run on Windows, macOS, Linux, and even on your Android and iPhone devices.

...with a learning system that's effective and fun

When you learn C#—when you learn to *really* be effective with it—you're learning more than just a language. You're learning a **whole new way of thinking**... and that's where we come in. We've spent more than 15 years developing, experimenting with, and testing out new and different ways to help you get C# ideas into your brain. You'll use **powerful programming environments** to build real projects and write lots of code. You'll learn and practice important **development ideas and patterns** that help you write great code. You'll learn how to use **modern AI tools** to superpower your code and level up your learning skills. By the time you're done, you'll have the foundation for successful and satisfying software development.

Welcome to the world of C#. Let's dive in!

Many people who used previous editions of this book have reached out to us over the years to tell us how our book helped them start their development careers. We're looking forward to hearing from you too!

“Head First C# started my career as a software engineer and backend developer. I am now leading a team in a tech company and an open source contributor.”

—**Zakaria Soleymani, Development Team Lead**

“Thank you so much! Your books have helped me to launch my career.”

—**Ryan White, Game Developer**



Write code and explore C# with Visual Studio

The best way to get started with C# is to **write lots of code**.

This book uses **pictures, puzzles, quizzes, stories, and games** to help you learn C# in a way that suits your brain. Every one of those elements is built to help you with a single goal: to keep things interesting while we help you get C# concepts, ideas, and skills into your brain.

This book is also **full of C# projects** that are *specifically designed* to give you lots of different ways to explore C# and learn about important ideas and concepts that will help you become a great developer. We designed those projects to be engaging, fun, and interactive to give you lots of opportunities to put those concepts, ideas, and skills into practice.

Visual Studio is your free gateway to C#

Learning C# is all about exploring and growing your skills *at your own pace*, and that's where **Visual Studio** comes in. It's an amazing tool built by Microsoft. At its heart, it's an editor for your C# code and projects, but it's much more than that. It's a creative tool that helps you with every aspect of C# development. We'll use Visual Studio throughout this book as an important tool to help you learn and explore C#.

Visual Studio is an **IDE**—that's short for *integrated development environment*—a text editor, visual designer, file manager, and debugger...it's like a multitool for everything you need to write code.

Here are just a few of the things that Visual Studio helps you do:

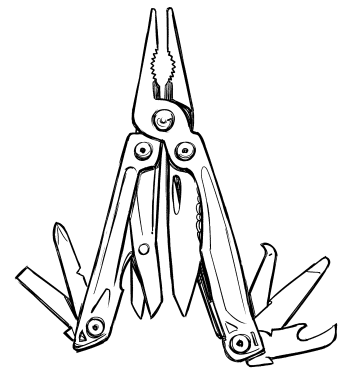
- ★ **It's a file and project manager.** C# projects are often made up of a lot of files. Visual Studio makes it easy to see exactly where they are, and integrates with version control systems like Git to make sure you never lose a line of code.
- ★ **It helps you edit and manage your code.** Visual Studio has many intuitive features to help you edit your code and C# projects, including powerful AI-driven tools like IntelliSense pop-ups and IntelliCode code completion that give you great suggestions to help keep you in the flow.
- ★ **It's a debugger that lets you see your code in action.** When you debug your apps in Visual Studio, you can see exactly what your code is doing while it runs—which is a great way to *really understand* how C# code works.

IDE Tips

We'll often refer to Visual Studio as **"the IDE"** throughout this book. Keep an eye out for handy IDE tips that help you become a more efficient coder.

← If you decide to use Visual Studio Code instead of Visual Studio, that's your IDE. They're both IDEs!

Visual Studio is only available for Windows. Luckily, you can also use *Visual Studio Code* to do all of the projects in this book. If you're using a Mac or Linux, or if you want to use Visual Studio Code instead of Visual Studio, skip ahead to the next section, where we'll show you how to set it up and use it to create your first C# project.

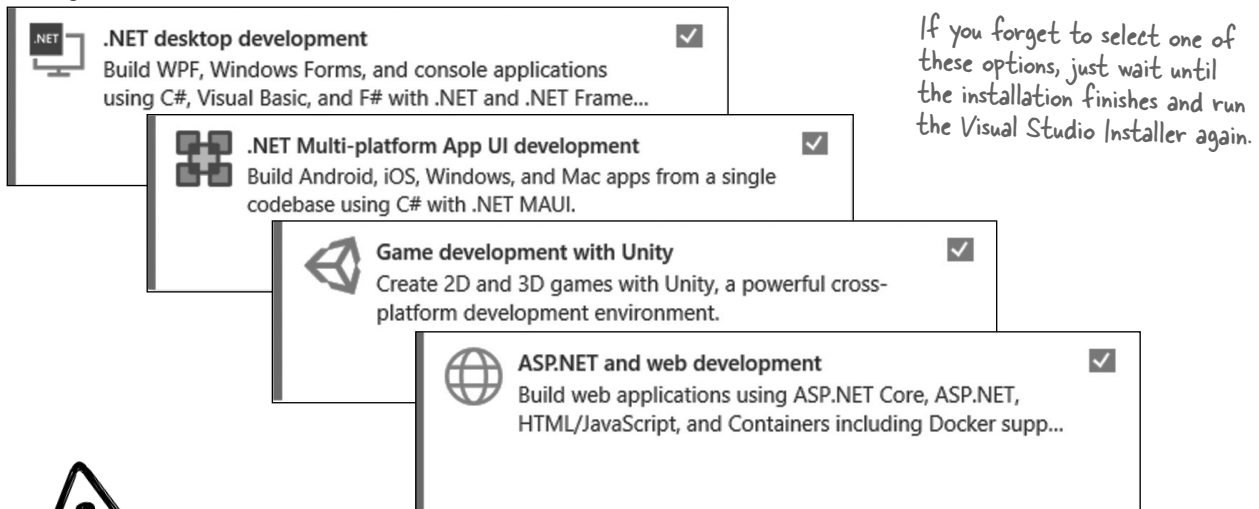


Visual Studio is a powerful development environment, and it's an amazing learning tool to help you explore C#.

Install Visual Studio Community Edition

Open <https://visualstudio.microsoft.com> and **download Visual Studio Community Edition**. It's available for both Windows and macOS. The installers look a little different depending on which platform you're using. Make sure you install the .NET desktop development tools and .NET Multi-platform App UI (or .NET MAUI) development tools. We'll be doing 3D game development with Unity, so make sure you check that option too.

When you run the Visual Studio installer, select the “.NET desktop development,” “.NET Multi-platform App UI development (MAUI),” and “Game development with Unity” options to install the Visual Studio tools you'll use in this book. You should also select “ASP.NET and web development” if you plan to download the **Head First C# Blazor Learner's Guide** and learn about web development with C#.



Watch it!

This book was written on a Mac. All of the Visual Studio and Unity screenshots in this book were taken running Windows 11 in a Parallels Desktop virtual machine.

You can use Visual Studio for Mac, but it's no longer supported by Microsoft.

Visual Studio for Mac was a great tool for learning C# on a Mac! But while we were finishing up this edition of Head First C#, Microsoft announced that they would stop development on it and end support in 2024. If you're using a Mac or Linux, the folks at Microsoft recommend running Windows virtual machine (VM) using software like VirtualBox or Parallels Desktop.

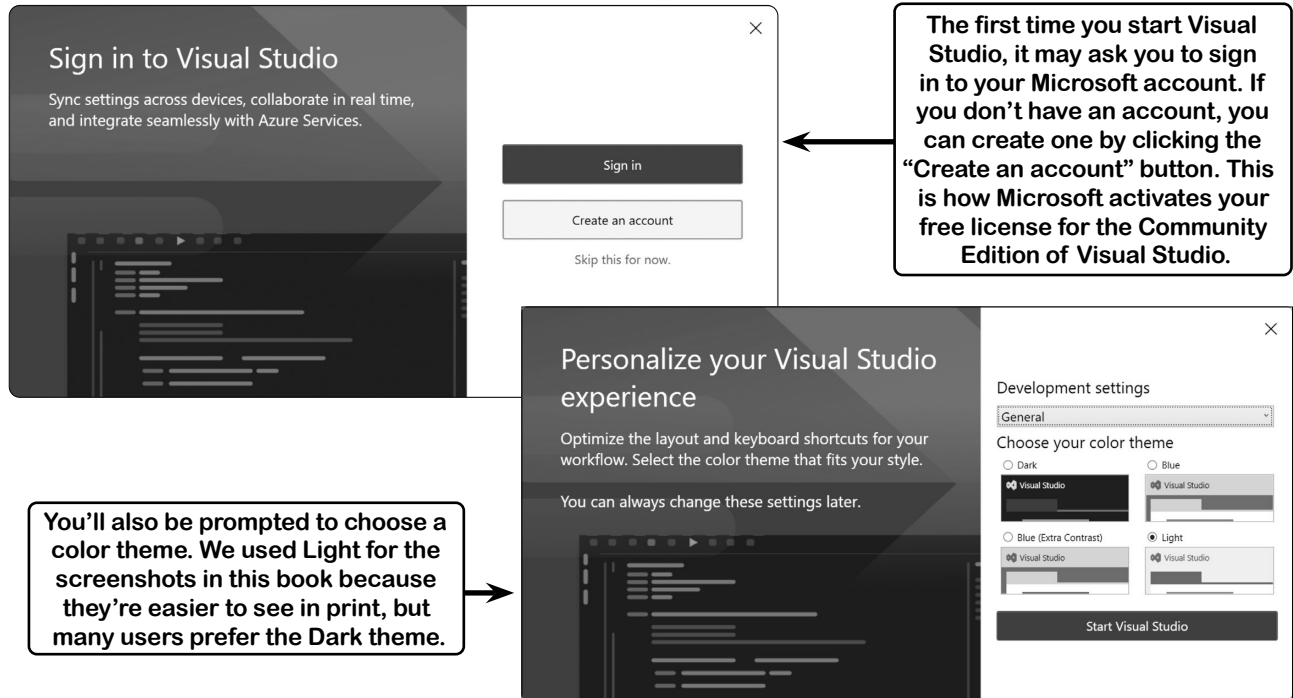
An easy way to get started is to download VirtualBox for free from <https://www.virtualbox.org> and then download a Windows virtual machine from Microsoft that contains an evaluation version of Windows from <https://developer.microsoft.com/en-us/windows/downloads/virtual-machines>.

*We'll also show you how to use **Visual Studio Code** later in the chapter.*

All of the projects in this book can be done in Visual Studio Code on Windows or macOS.

Run Visual Studio

We're going to jump right into code! Once the installer finishes, **run Visual Studio**.



Keep an eye out for these “relax” boxes—they point out some common issues that a lot of readers run into, so you know they’re coming and don’t have to worry about them.

Relax

Grab a cup of coffee—it can take some time for Visual Studio to install.

Don't worry if it takes a few minutes (or more!) to finish installing Visual Studio. And while we're on the subject, here's something else that you don't have to worry about.

All of the screenshots in this book were taken with **Visual Studio 2022 Community Edition**, the latest version available while we were writing it. If Microsoft released a newer version of Visual Studio since we took these screenshots, feel free to try it! The code and ideas that we teach should still work just fine. But if you want the screenshots to match, Microsoft makes older versions of Visual Studio available for download—and you can always install different versions of Visual Studio on the same computer:
<https://visualstudio.microsoft.com/vs/older-downloads>

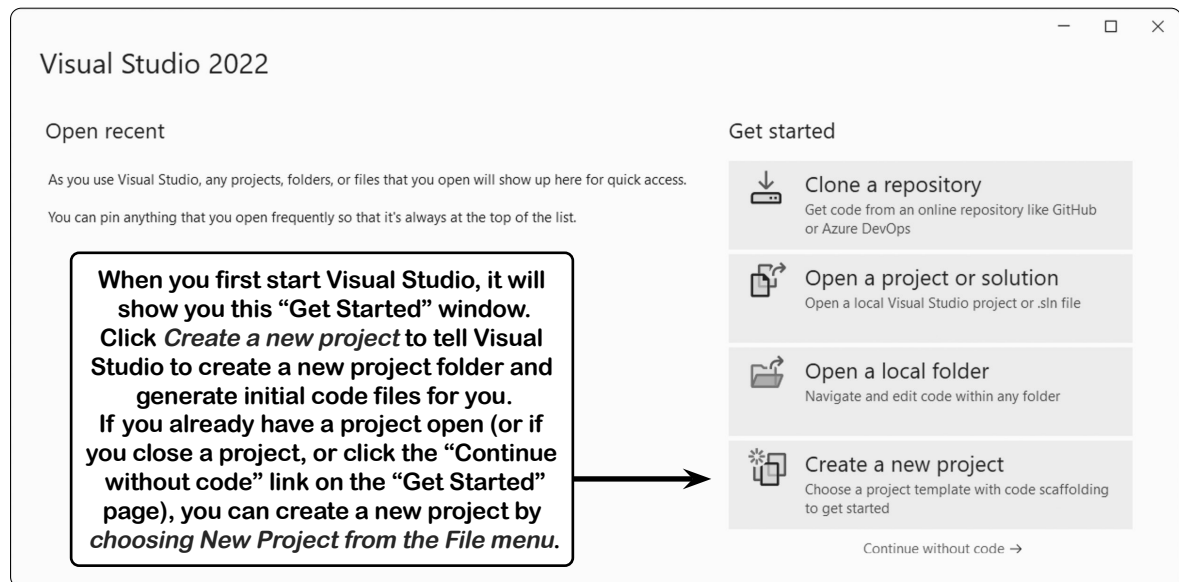
If you run into trouble installing Visual Studio or running your first project, head to our YouTube channel (<https://www.youtube.com/@headfirstcsharp>) to see videos of the entire installation process.

Create and run your first C# project in Visual Studio

The best way to learn C# is to start writing code, so you're going to write a lot of code—and create a lot of apps!—throughout this book. Each app will get its own **project**, or a folder that Visual Studio creates with special files to organize all of the code.

1 Tell Visual Studio to create a new project.

When you launch Visual Studio, the first thing you'll see is a Get Started window with four options. Click **“Create a new project”** to create a new project.



When you create a new project, Visual Studio will ask you which of its **project templates** you want to use. Every C# project consists of a set of folders and files. Visual Studio has many built-in templates that it can use to generate different kinds of projects. In this book, you'll use Visual Studio's templates to create three kinds of projects: Console App projects, .NET MAUI projects, and MSTest unit test projects. (You'll also create Unity projects, but you won't use Visual Studio to create them.)



Let's write some code!

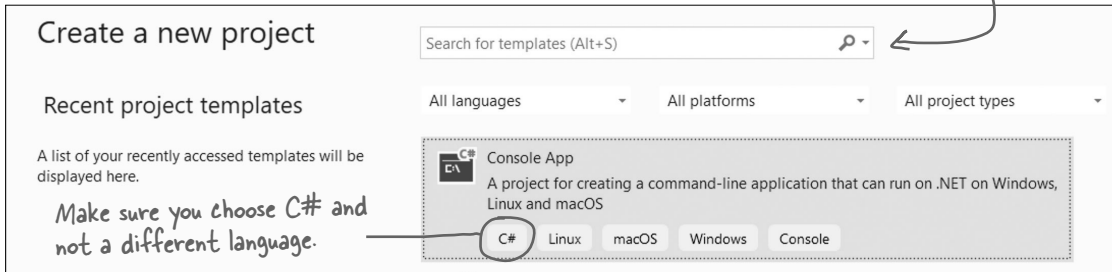
You'll be writing a lot of code throughout this book, which means you'll be **creating a lot of projects**. Most of those projects will be **Console App projects**, just like the one you're creating now—so you can follow these directions any time you need to create a new Console App project. Just make sure you choose a different project name each time so that Visual Studio creates the project in a new folder (don't worry—it will warn you if that name already exists).

2

Choose a project template for Visual Studio to use.

Visual Studio creates new projects using a *template* that determines what files to create. **Choose the Console App template** and click Next.

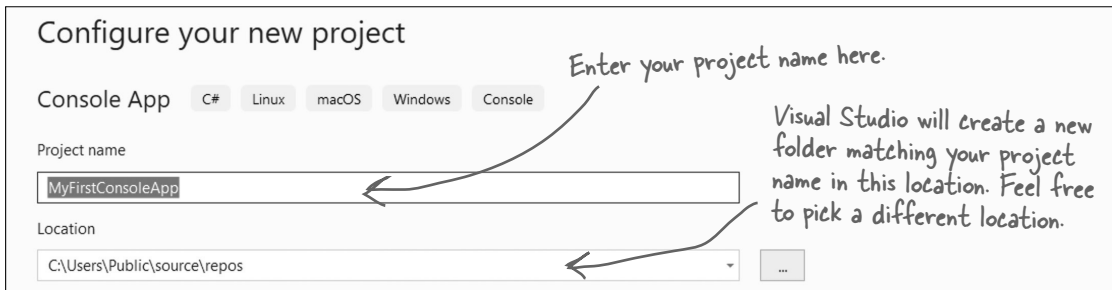
Enter "Console App" in the search box or scroll down to the Console App template.



3

Enter a name for your project and click Next.

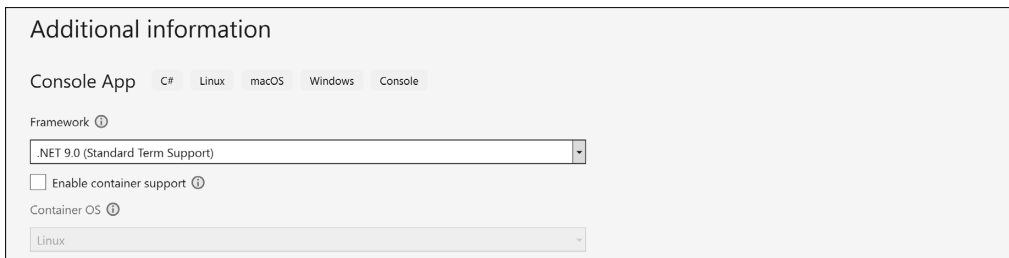
Your project's name is important—it determines file and folder names, and you'll see it inside some of the code that Visual Studio generates for you. If we ask you to pick a specific name, make sure you do; otherwise, the code in your project may not match screenshots in the book.



4

Make sure you're using the current version of .NET.

The current version of .NET at the time we're writing this is 9.0—make sure the version that you're using is 9.0 (or higher). Then **click the Create button** to create your project.



Once Visual Studio creates your project, it will open a file called *Program.cs* with this code:



run your new C# project

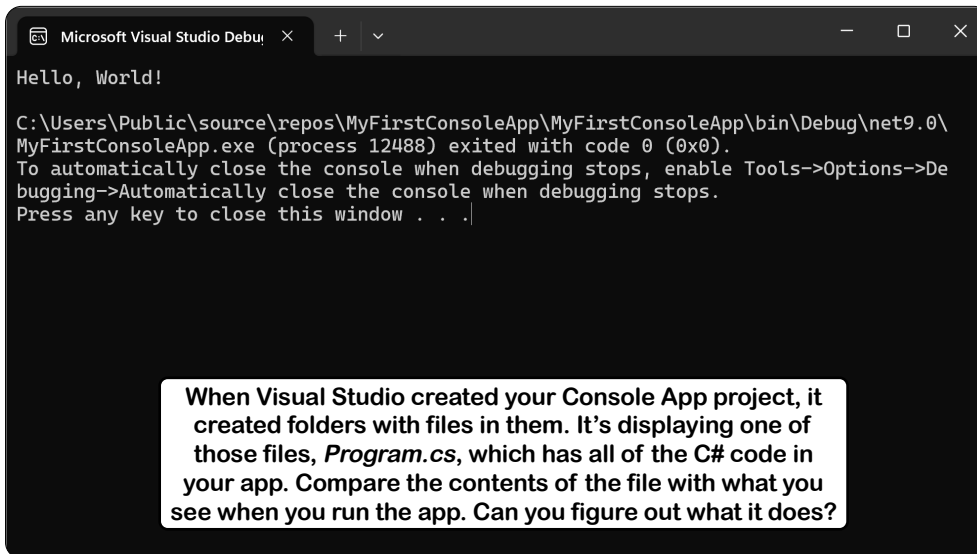
5 Run your app.

The app Visual Studio created for you is ready to run. At the top of the Visual Studio IDE, find the button with a green triangle and your app's name and click it:



6 Look at your app's output.

When you run your program, the **Microsoft Visual Studio Debug Console window** will pop up and show you the output of the program:



```
Microsoft Visual Studio Debug Console
Hello, World!
C:\Users\Public\source\repos\MyFirstConsoleApp\MyFirstConsoleApp\bin\Debug\net9.0\MyFirstConsoleApp.exe (process 12488) exited with code 0 (0x0).
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

When Visual Studio created your Console App project, it created folders with files in them. It's displaying one of those files, *Program.cs*, which has all of the C# code in your app. Compare the contents of the file with what you see when you run the app. Can you figure out what it does?

At the top of the window is the **output of the program**:

Hello, World!

Then there's a line break, followed by some additional text:

```
C:\path-to-your-project-folder\MyFirstConsoleApp\MyFirstConsoleApp\bin\Debug\net9.0\MyFirstConsoleApp.exe (process ####) exited with code 0.
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

You'll see the same message at the bottom of every Debug Console window. Your program printed a single line of text (**Hello, World!**) and then exited. Visual Studio is keeping the output window open until you press a key to close it so you can see the output before the window disappears.

Press a key to close the window. Then run your program again.

This is how you'll run all of the Console App projects that you'll build throughout the book.

Sharpen your pencil

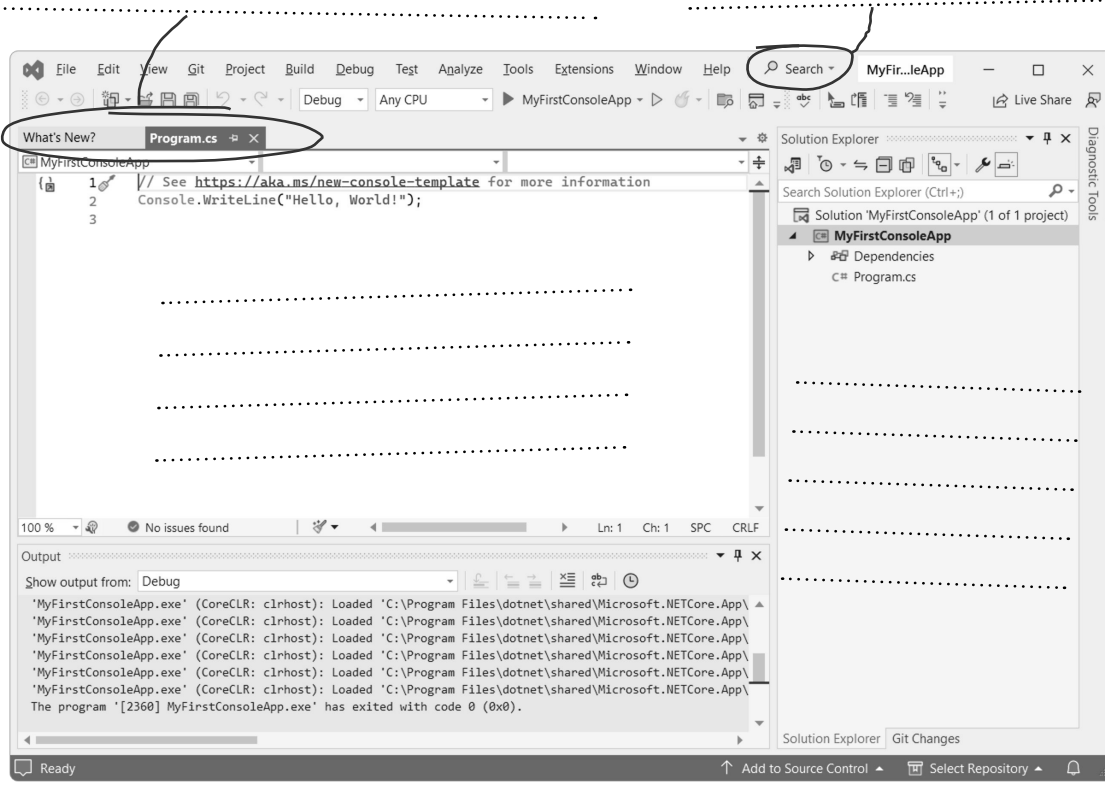
Visual Studio is a great tool to help you learn and explore C#. You're going to be writing a lot of code throughout this book, so this is a great time to get familiar with it.

Visual Studio is an IDE, or integrated development environment. If you haven't used an IDE before it may look very busy, so this is a great time to get used to it. One of the most important ways to get new ideas, information, skills, and tools to stick in your brain is to **write them down**. So take a close look at the different parts of Visual Studio and write down what you think they do. It's OK if you aren't 100% sure—just take your best guess!

.....

.....

.....



When you created your app, it contained a file with two lines. Write down what you think each line does.

`// See https://aka.ms/new-console-template for more information.`

.....

`Console.WriteLine("Hello, World!");`

.....

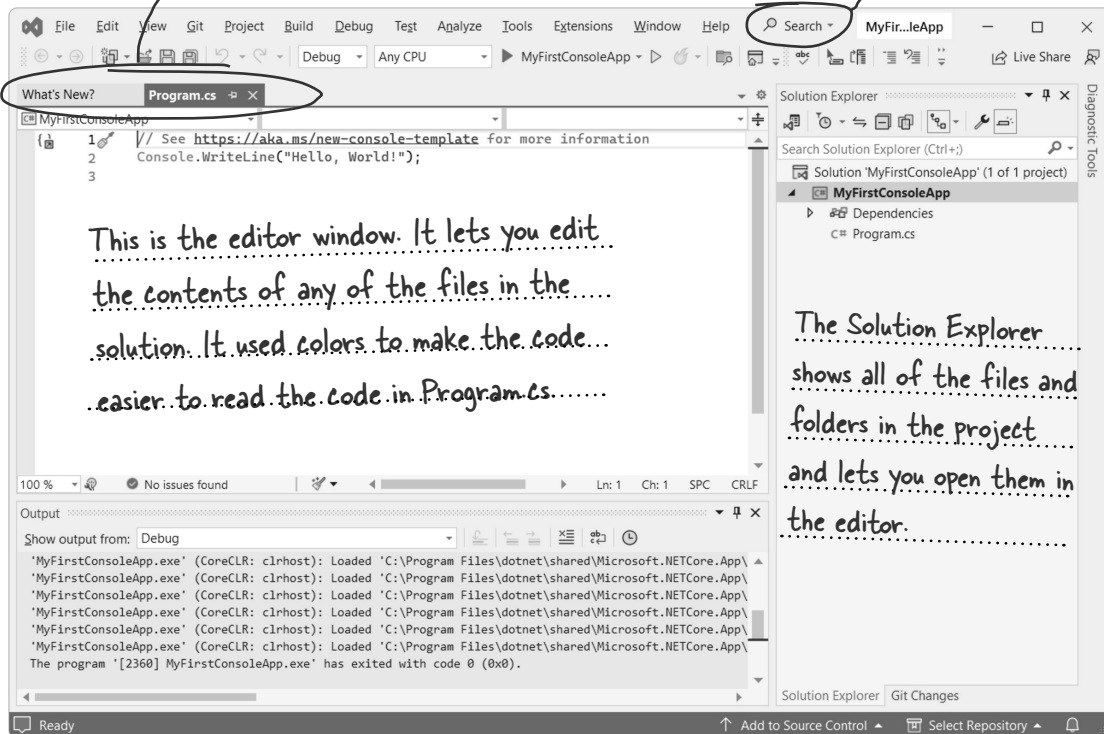
get familiar with your tools

Try moving the panels in Visual Studio around. Click the pushpin button (📌) to collapse the Solution Explorer window into the side panel. Reset the layout by choosing Reset Window Layout from the Window menu, then use the View menu to open other windows.

Sharpen your pencil Solution

You can open multiple files at the same time and use these tabs to switch between them. Visual Studio displayed the "What's New?" tab when you opened it.

The Search button opens a window that lets you search the code in your project and find features in Visual Studio.



This is the editor window. It lets you edit the contents of any of the files in the solution. It used colors to make the code easier to read the code in Program.cs.

The Solution Explorer shows all of the files and folders in the project and lets you open them in the editor.

When you created your app, it contained a file with two lines. Write down what you think each line does.

```
// See https://aka.ms/new-console-template for more information.
```

This is a comment, it doesn't do anything. It just provides information to the person reading it.

```
Console.WriteLine("Hello, World!");
```

This line of code causes the app to print the text "Hello, World!" (without the quotation marks).

Keep an eye out for these Q&A sections. They often answer your most pressing questions, and point out questions other readers are thinking of. In fact, a lot of them are real questions from readers of previous editions of this book!

there are no
Dumb Questions

Q: So if Visual Studio writes code for me, is learning C# just a matter of learning how to use it?

A: No. The IDE is great at automatically generating some code for you, but it can only do so much. There are some things it's really good at, like setting up good starting points for you, and automatically changing properties of controls in your UI. It did all of that by taking the information you gave it and feeding it into a template that generated files. The most important part of programming—figuring out what your program needs to do and making it do it—is something that no IDE can do for you. Even though the Visual Studio IDE is one of the most advanced development environments out there, it can only go so far. It's *you*—not the IDE—who write the code that actually does the work.

Q: What if the IDE creates code I don't want in my project?

A: You can change or delete it. The IDE is set up to create code based on the way the element you dragged or added is most commonly used, but sometimes that's not exactly what you wanted. Everything the IDE does for you—every line of code it creates, every file it adds—can be changed, either manually by editing the files directly or through an easy-to-use interface in the IDE.

Q: Why did you ask me to install Visual Studio Community Edition? Are you sure that I don't need to use one of the versions of Visual Studio that isn't free to do everything in this book?

A: There's nothing in this book that you can't do with the free version of Visual Studio (which you can download from Microsoft's website). The main differences between Community and the other editions aren't going to stop you from writing C# and creating fully functional, complete applications. (The paid editions have additional features that are useful for professional software organizations and teams.)

Q: My screen doesn't look like yours! It's missing some of the windows, and others are in the wrong place. Did I do something wrong? How can I reset it?

A: If you click on the **Reset Window Layout** command under the Window menu, the IDE will restore the default window layout for you. Then use the **View** menu to open any windows that are missing. You can find some of the windows you'll see later in this chapter in its **Other Windows** submenu. That will make your screen look like the ones in this chapter and throughout the book.

Some windows collapse by default. Use the pushpin button in the upper-right corner of the window to make it stay open.

Visual Studio will generate code you can use as a starting point for your applications. Making sure the app does what it's supposed to do is entirely up to you.

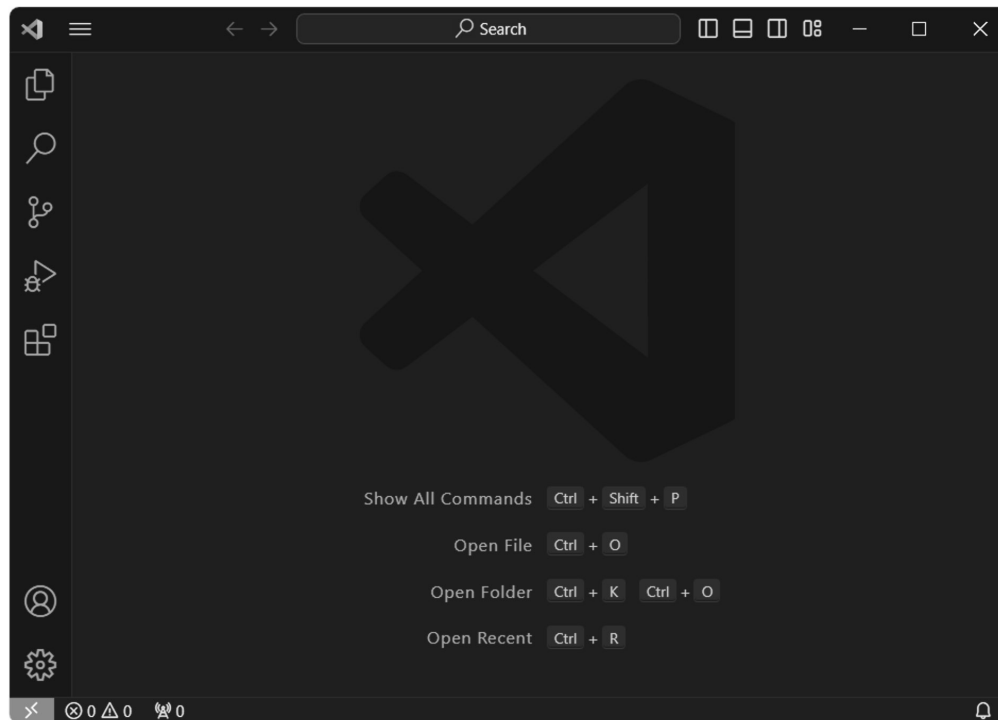
You can use Visual Studio Code with Head First C#

If you're using Visual Studio (and not VSCode), you can skip ahead to “Let's Build a Game!”

If you've been around the development world at all over the last few years, you've probably heard a lot of buzz and excitement about **Visual Studio Code** (often called **VSCode**). It's a powerful code editor that runs on Windows, Mac, and Linux, and it's gotten very popular among developers because it's easy to use, versatile, fast, and intuitive.

If you're using Windows, we recommend that you consider using Visual Studio (*not* VSCode) because it's specifically built for C# and has some built-in tools that VSCode currently lacks. However, ***all of the projects in this book can be done with VSCode***. Most of the screenshots in this book will show Visual Studio, but we'll also tell you how to do the same thing in VSCode where it differs from Visual Studio.

To use this book with Visual Studio Code, start by downloading it from <https://code.visualstudio.com>. Run the installer, and choose all of the default options. After the installer finishes, open VSCode. It will prompt you to choose a color theme. We chose Dark Modern for our screenshots because we used a light theme for Visual Studio, so choosing a dark theme for VSCode will help make it easier to tell the screenshots apart.




The first time you run VSCode, it shows you a Welcome tab with a bunch of settings you can choose, including color theme. You can go through those settings, or you can just close the tab.

Using Visual Studio Code is optional. You can use VSCode to do all of the projects in this book on Windows or macOS. (Linux readers may need to run an Android emulator to do the .NET MAUI—we'll talk about that later.)

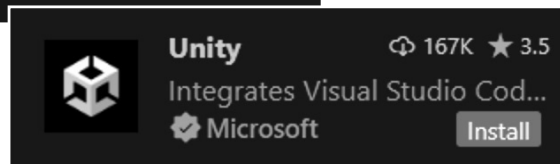
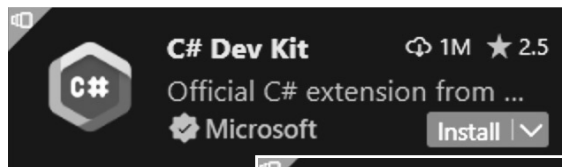
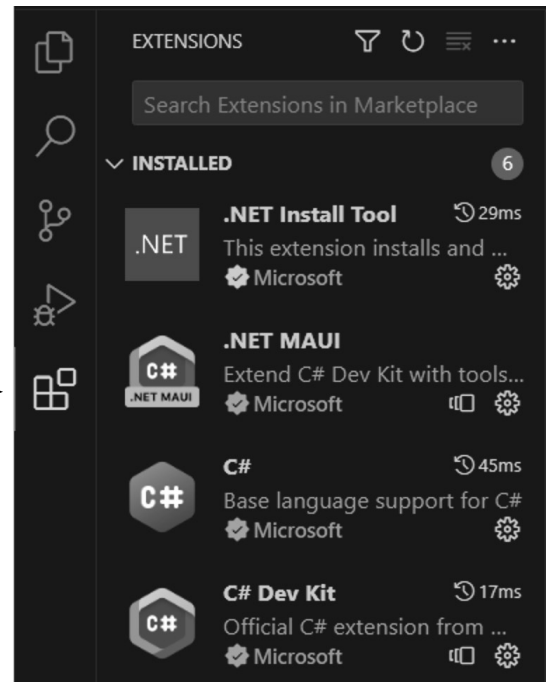
If you have trouble installing VS Code or running your first project, head to our YouTube channel (<https://www.youtube.com/@headfirstcsharp>) to see videos of the entire Windows or macOS installation process.

Install the C# extensions

Click the **Extensions** button  on the left side of the VSCode window to open the Extensions panel. At the top of the panel is a search box with the text “Search Extensions in the Marketplace.” **Search for each of these extensions:**

- ★ **C# Dev Kit:** This extension has the tools you need to create, edit, and debug C# and .NET projects.
- ★ **.NET MAUI:** Most chapters in this book have a project that uses .NET MAUI, a framework for creating desktop and mobile apps in C#.
- ★ **Unity:** The Unity Labs give you a chance to practice your C# skills by building 3D games and simulations.

Make sure each extension is the official one from Microsoft. Click the **Install** button on each extension to install it.



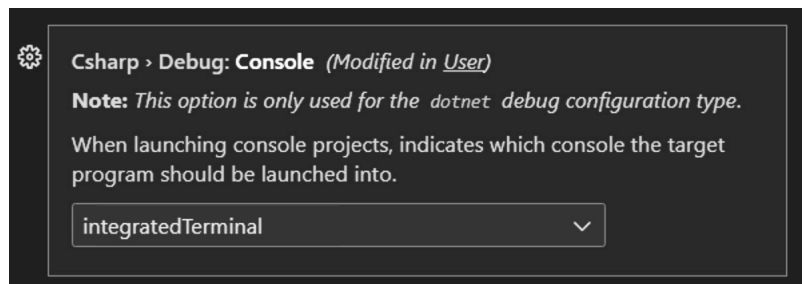
← VSCode may prompt you to restart after installing extensions. It may also display Getting Started tabs that have useful information.

This setting tells VSCode where to show the output of your app. Set it to use the Terminal window; otherwise, some apps you build later in the book won't work.

Change the C# debug console setting


Once you have your extensions set up, click the gear icon in the lower-left corner of the VSCode window and choose Settings (or press Ctrl comma or ⌘ comma). Search for the setting **csharp.debug.console**—you should see a dropdown with several options. Change the setting to **integratedTerminal**.

Now you're ready to write some C# code!




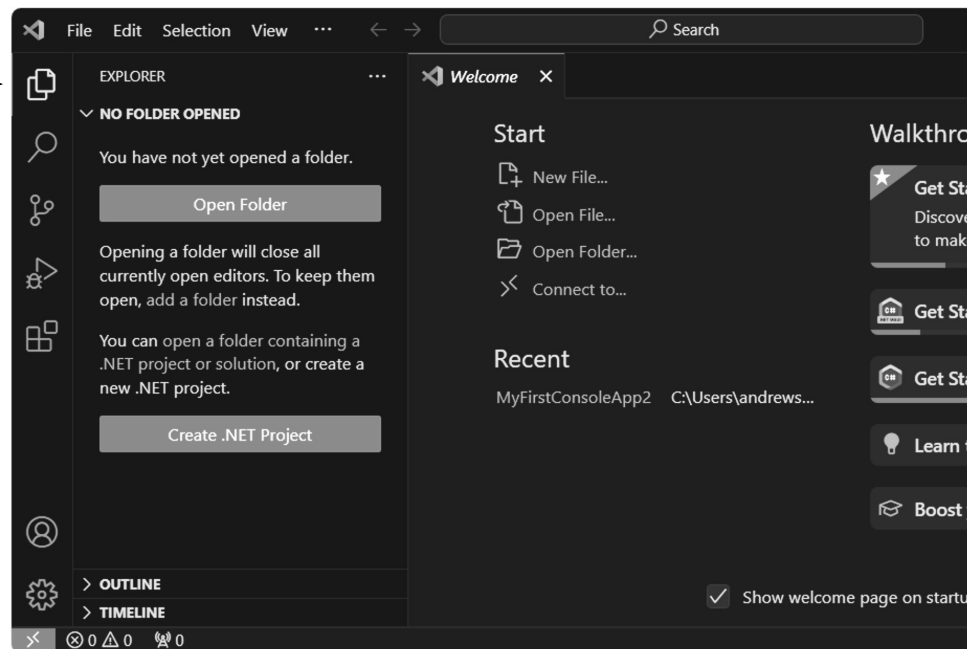
Create and run your first project in Visual Studio Code

Visual Studio Code is first and foremost an **editor**, which means its features are specialized for opening and editing many different kinds of files. A VSCode window is typically used to edit files in a **folder** and its subfolders. When you open VSCode, it remembers the most recent folder you opened. But when you first open it, you'll need to select a folder. We'll walk you through the steps for creating a folder with a new .NET project in it.

On Windows, the menu is at the top of the window (if you make the window very narrow, click the menu button  to display it). On macOS, you'll see the menu in the menu bar at the top of the screen.

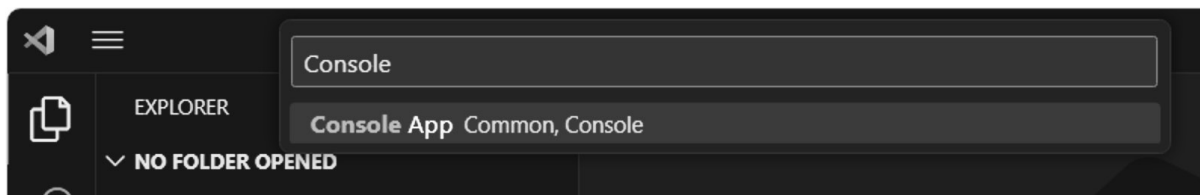
Click this button to open and close the lefthand panel. If VSCode does not currently have a folder open, the panel will have buttons to open a folder and create a new .NET project.

If you don't see the Create .NET Project button, you can open the Command Palette (Ctrl+Shift+P or  P) and choose .NET: New Project from the menu that's displayed.



1 Click the Create .NET Project button.

A box will appear at the top of the VSCode window with a list of project types, and a search box with the prompt "Select a template to create a new .NET Project." **Type Console into the search box**, then choose Console App from the list of templates to create a new .NET Console App project.



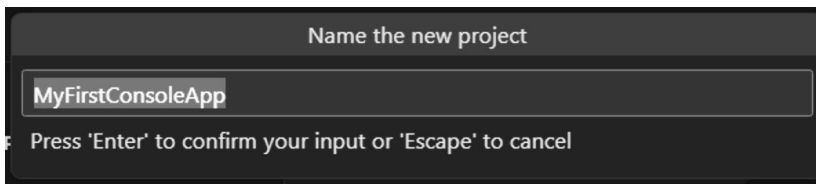
2 Select a folder for your new project.

VSCode will display a folder browser window. **Choose a location for your new project.** The folder browser window has a “New folder” button. You’ll be creating a lot of projects throughout this book, so we suggest creating a folder called “Projects” underneath your home folder or Documents folder to hold them.

Create a new folder inside the folder where you keep your projects and **name it *MyFirstConsoleApp***. Then navigate to the *MyFirstConsoleApp* folder that you just created and **click Select Folder**.

3 Give your project a name.

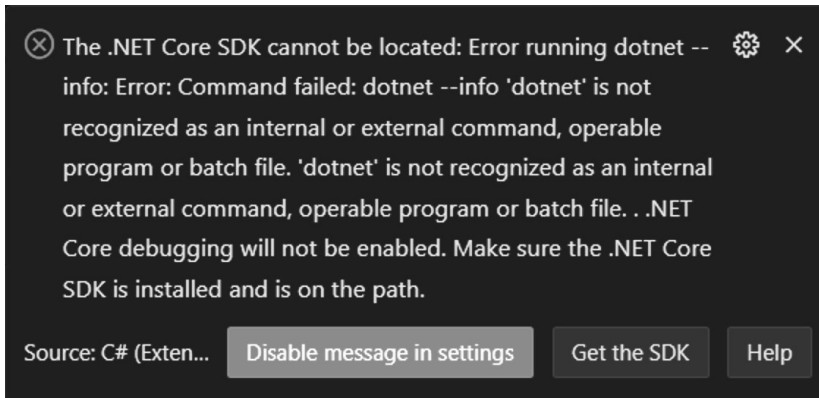
Every C# project has a name. You’ll usually give the project folder the same name as the project. After you select your folder, VSCode will prompt you for a project name:



Type *MyFirstConsoleApp* into the box, then press the Enter key to create the project. VSCode may ask you if you trust the authors of the folder. This is a really useful security feature, because it prevents you from accidentally opening malicious code. **Click the “Yes, I trust the authors” button**. You have the option of checking a box to always trust everything in your projects folder.

4 Install the .NET Core SDK. (You only need to do this once!)

Before you can create and run C# and .NET apps, you need to install the **.NET Core SDK**. The easiest way to do this on Windows is to install Visual Studio 2022. If you don’t have the SDK installed, VSCode will display a window prompting you to get it. **Click the “Get the SDK” button**—this opens a browser window with the page <https://dot.net/core-sdk-vscode>. Follow the instructions to download the latest version of your SDK for your operating system. Be careful to choose the architecture that matches your computer. For Mac users: if your Mac was made after 2019, choose Arm64; if you’re using an older Intel Mac, choose Intel.



Visual Studio Code is really popular with a lot of developers because it’s lightweight, open source, and has a huge ecosystem of extensions and tools. But using it will require you to do a little more manual work like this, which is why we recommend using Visual Studio instead.

5 Expand the Solution Explorer and open *Program.cs*.

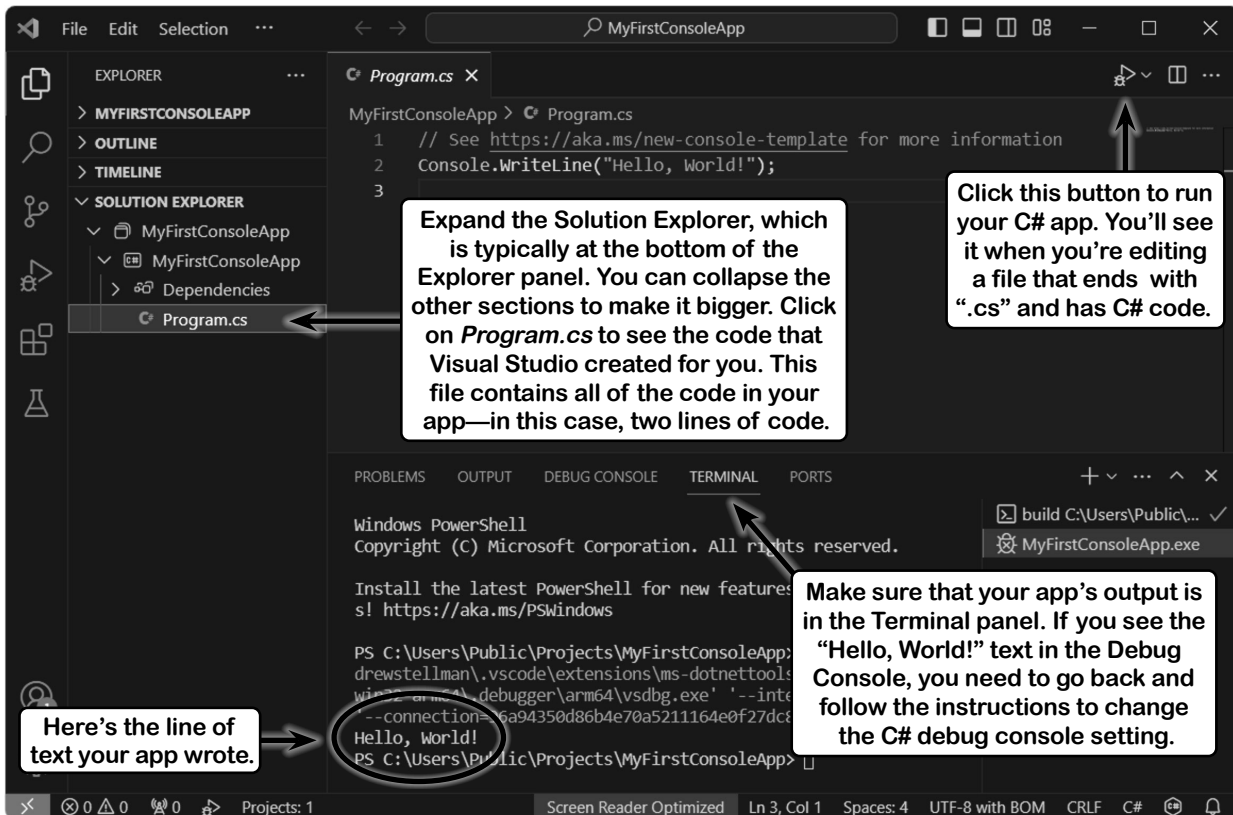
After VSCode creates your C# project, the Explorer panel on the left will contain several collapsible sections. VSCode is file- and folder-based, and the **Explorer** is used to browse those files and open them for editing.

Expand the Solution Explorer section at the bottom of the Explorer. The Solution Explorer is part of the C# Dev Kit, which lets VSCode work with C# projects. It shows you all of the files and subfolders that VSCode created for your project—in this case, your app has one file with C# code called *Program.cs*. **Click *Program.cs*** in the Solution Explorer to open the file.

6 Run your app.

When you have a C# code file (a file that ends with *.cs*) open in the Solution Explorer, you'll see a Run button (🚀) in the upper-right corner of the window. Click that button to run the app.

You can also **press F5** and choose “Start Debugging” from the Run menu to run your app. VSCode may prompt you to select a debugger. If it does, choose C#. If it asks for a launch configuration, choose the one that matches the project name. You can press F5 any time you want to run your app. Your app will start running, and Visual Studio will open the **Debug Console panel** to show you the output and let you interact with it. ***This is how you'll run all of the Console App projects that you'll build throughout the book.***



Set up Visual Studio Code for the next project

VSCoDe is a great code editor! But unlike Visual Studio, it's not designed specifically for C# and .NET projects. It does a great job with C#, but you need to do a little extra work to get it up and running.

First open a folder, then add a project

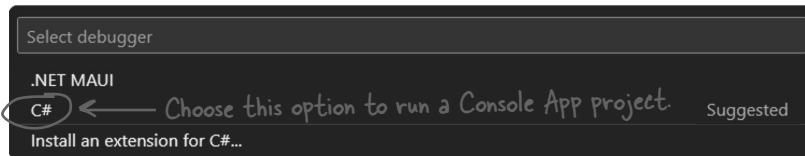
VSCoDe is extremely flexible, and there are many ways to use it. If you're new to VSCoDe, we recommend that you **create a new folder for every project in the book**. When you start a new project, **choose Close Folder** from the File menu to close the current folder, then create a new folder and open it.

This is how you reset VSCoDe so you can start a new project.

The Command Palette

All of the actions that you need to do to create and run projects can be run from the **Command Palette**, the centralized hub for all of the VSCoDe features. Press Ctrl+Shift+P (or ⌘⇧P on a Mac) to display the Command Palette. Use the .NET: New Project to create a new project in the current folder. There are also commands to open and close .NET solutions. You'll learn more about solutions throughout this chapter.

When you have a .NET app's project folder open, you can run it by choosing **Debug: Start Debugging** from the Command Palette. Choose the C# option to start running your Console App project.



You'll need to install .NET MAUI before you move on to the rest of the chapter. If you're using Visual Studio 2022 you already installed it, but if you're using VSCoDe you'll need to do it manually.

Install .NET MAUI before reading the rest of this chapter

In the rest of this chapter, you'll build a game using **.NET MAUI** (Multi-platform App UI), a powerful cross-platform framework that lets you create visual apps in .NET and C# that can run on Windows, macOS, Android, and iOS.

Before you can install and run your .NET MAUI apps, you'll need to install the **.NET MAUI workload for .NET**. The easiest way to do this on Windows is to install Visual Studio 2022 and choose the .NET MAUI option.

You can also install .NET MAUI from the command line. Typically it looks like this:

```
dotnet workload install maui or sudo dotnet workload install maui
```

If you're using a Mac or Linux, you may need to use **sudo** to run with elevated privileges. If you're on a Mac, you'll also need to **install XCode**. You can install the Android SDK as well (but it's optional). See this page for more details: <https://learn.microsoft.com/dotnet/maui/get-started/installation?tabs=visual-studio-code>

If you're using Linux, you'll need an Android device for the .NET MAUI projects

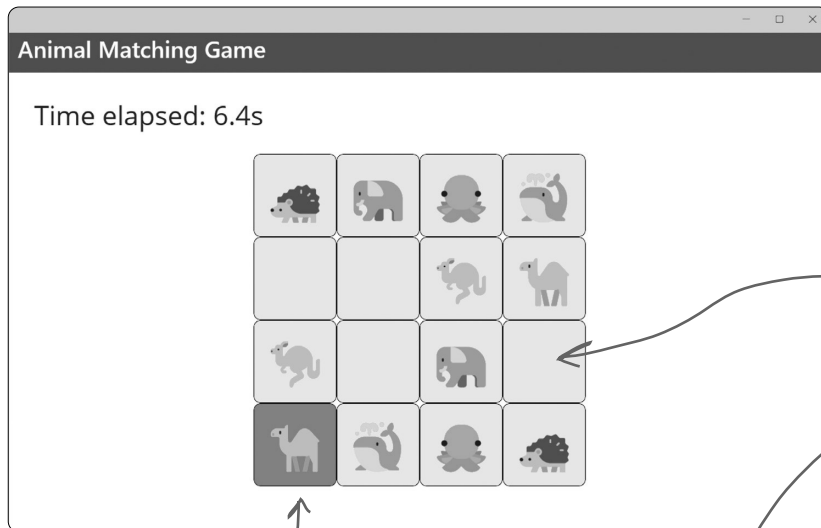
.NET MAUI does not run natively on Linux. If you have an Android device, you can debug directly on it. This page shows you how to set up an Android device so you can connect it to your computer and run your MAUI apps on it: <https://learn.microsoft.com/dotnet/maui/android/device/setup>

As an alternative, every MAUI project in this book has a Blazor alternative, where you'll build a web app version that runs in a browser. Download the **Head First C# Blazor Learner's Guide** from our GitHub page for more information—you can get it as a free PDF: <https://github.com/head-first-csharp/fifth-edition>

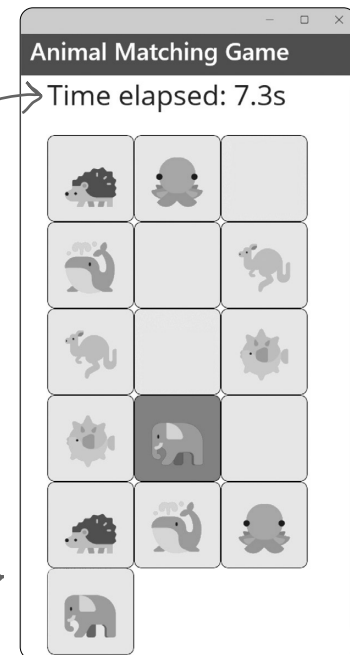
Let's build a game!

You've built your first C# app, and that's great! Now that you've done that, let's build something a little more complex. We're going to build an **animal matching game**, where a player is shown eight pairs of animals and needs to click on them in pairs to make them disappear.

The game displays 16 buttons with eight pairs of matching animals in a random order. You play by clicking animals in pairs: first click one animal, then click its match. Match all eight animals and you win the game!



When you click a matched pair of animals, they both disappear.



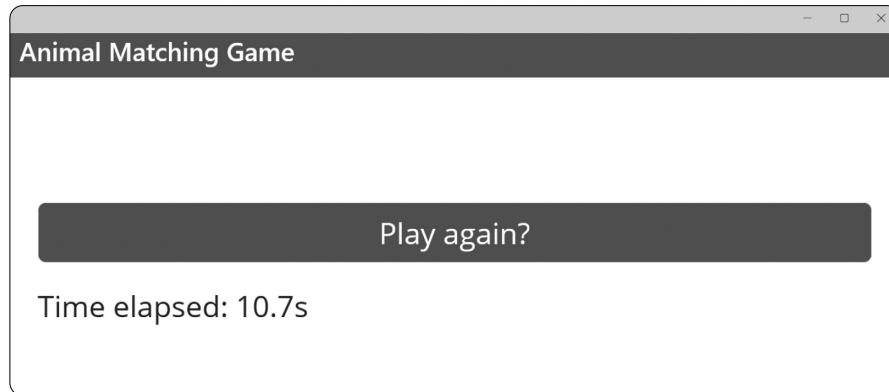
When you click the first button, it changes color. If you click on its match, then both animals disappear. If you click any other animal, the color of the first button changes back and you have to start over with a new pair.

To make things more exciting, the game starts a timer as soon as you start the game. Can you beat your best time?

You can change the size of the window and the animal buttons will rearrange themselves out to fill up the new width.

The rest of this chapter is dedicated to walking you through creating the Animal Matching Game project. This project is built with .NET MAUI, a cross-platform framework for building desktop and mobile apps. There are several MAUI projects scattered throughout this book. You also have the option of using these projects to *learn about web development* using Blazor, Microsoft's powerful web development framework. Download the Head First C# Blazor Learner's Guide—it's a free PDF with web versions of every MAUI project in this book (<https://github.com/head-first-csharp/fifth-edition>).

When you've found all eight pairs of animals, the game displays a big "Play again?" button, with your final time underneath it. Click the button to reset the game and start over again!



Keep an eye out for these "Game Design...and Beyond" elements scattered throughout the book. We'll use game design principles as a way to learn and explore important programming concepts and ideas that apply to any kind of project, not just video games.



Game Design...and Beyond

What is a game?

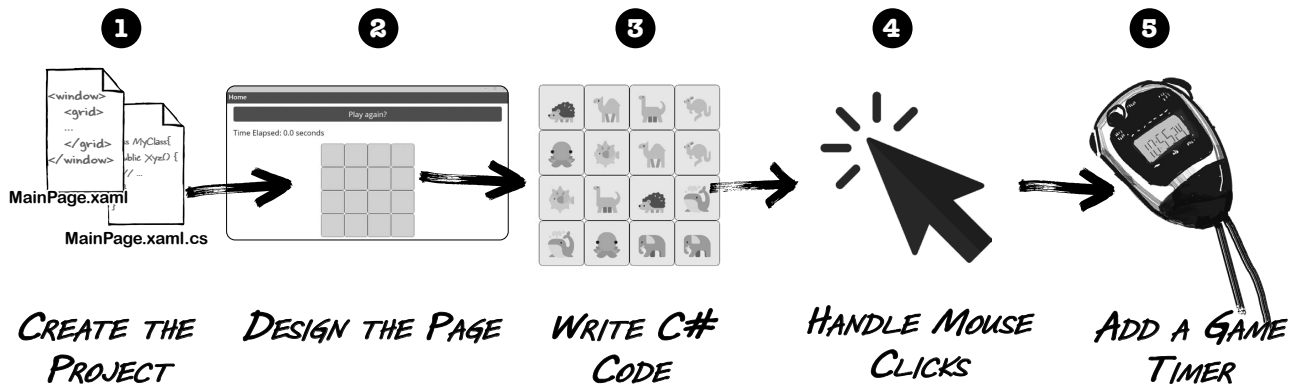
It may seem obvious what a game is. But think about it for a minute--it's not as simple as it seems.

- * Do all games have a **winner**? Do they always end? Not necessarily. What about a flight simulator? A game where you design an amusement park? Or a farming simulator? What about a game like The Sims?
- * Are games always **fun**? Not for everyone. Some players like a "grind" where they do the same thing over and over again; others find that miserable.
- * Is there always **decision making, conflict, or problem solving**? Not in all games. Walking simulators are games where the player just explores in an environment, and there are often no puzzles or conflicts at all.
- * It's actually pretty hard to pin down exactly what a game is. If you read textbooks on game design, you'll find all sorts of compelling definitions. So for our purposes, let's define the **meaning of "game"** like this:

A game is a program that lets you play with it in a way that (hopefully) is as entertaining to play as it is to make.

Break up large projects into smaller parts

Our goal in this book is to help you to learn C#, but we also help you **become a great developer**, and one of the most important skills great developers work on is tackling large projects. You'll build a lot of projects throughout this book. They'll be smaller starting with the next chapter, but they'll get bigger as you go further. As the projects get bigger, we'll show you how to break them up into smaller parts that you can work on one after another. This project is no exception—it's a larger project, like the ones you'll do later in the book—so you'll do it in five parts.



The goal of this project is to help get you used to writing C# and using the IDE. If you run into any trouble with this project, you can watch a full video walkthrough on our YouTube channel: <https://www.youtube.com/headfirstcsharp>

You can download all of the code and a PDF of this chapter from our GitHub page: <https://github.com/head-first-csharp/fifth-edition>

Relax

This chapter is all about learning the basics, getting used to creating projects, editing code, and building your game.

Don't worry if there are things that you don't understand yet. By the end of the book, you'll understand everything that's going on in this game. For now, just follow the step-by-step instructions to get your game up and running. This will give you a solid foundation to build on later.

Here's how you'll build your game

You'll build your animal matching game using **.NET MAUI** (which stands for .NET Multi-platform App UI, or just **MAUI**). MAUI is a technology that you can use to create apps in C# that run natively as desktop apps on Windows and macOS, or as mobile apps on your Android or iOS mobile devices.

The rest of this chapter will walk you through building the game. You'll be doing it in a series of separate parts:

- 1 First you'll create a new .NET MAUI project in Visual Studio.**
You just created a new console application. Now you'll create a new MAUI app.
- 2 Then you'll use XAML to design the page.**
Individual screens in MAUI apps are called **pages**. You'll design them using XAML, a design language you'll use to define how those pages work.
- 3 You'll write C# code to add random animal emoji to the page.**
When your app first loads, it will run that code to display 16 buttons with eight pairs of animal emoji in a random order.
- 4 You'll make the gameplay work.**
The game needs to detect when the user clicks on pairs of emoji, keep track of the pairs, and end the game when they've found all of the matches. You'll write that code too.
- 5 Finally, you'll make the game more exciting by adding a timer.**
Your timer will start when the player starts the game, and keep track of how long it takes the player to find all eight pairs of animals.

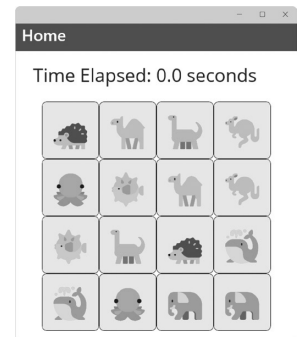
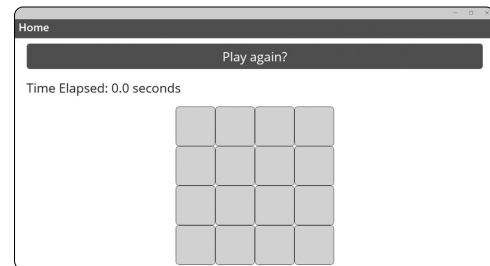
This project can take anywhere from 20 minutes to over an hour, depending on how quickly you type. We learn better when we don't feel rushed, so give yourself plenty of time.

```

<FlexLayout>
  <Button/>
  ...
  <Button/>
</FlexLayout>
MainPage.xaml

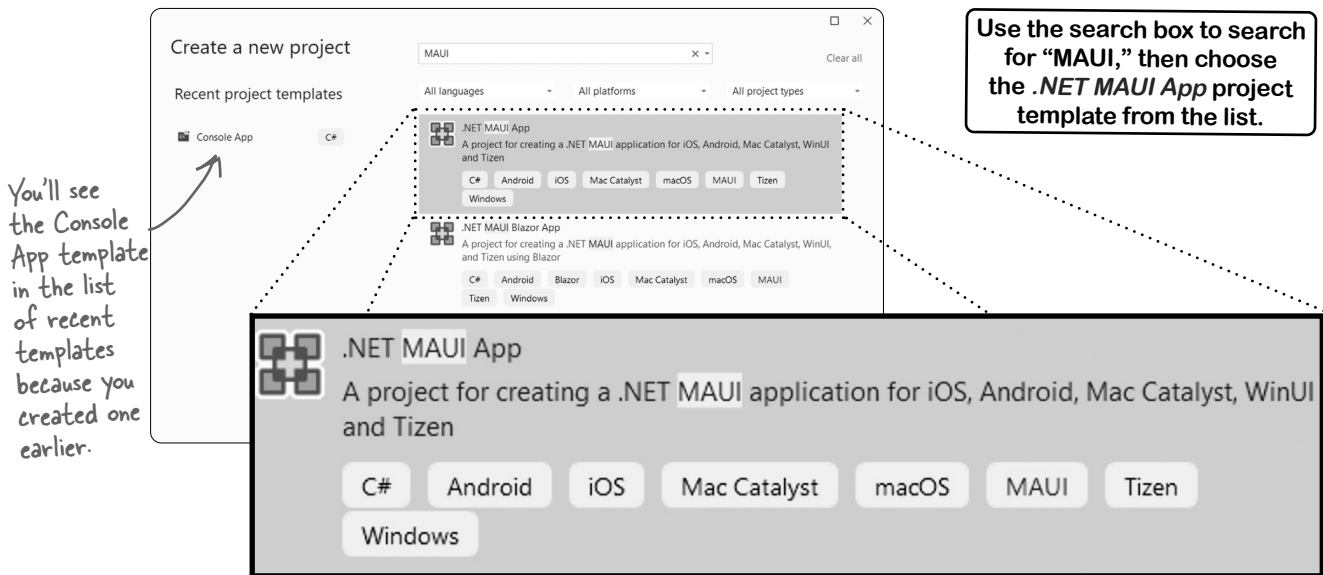
class MyClass {
  void Xyz() {
    // ...
  }
}
MainPage.xaml.cs

```



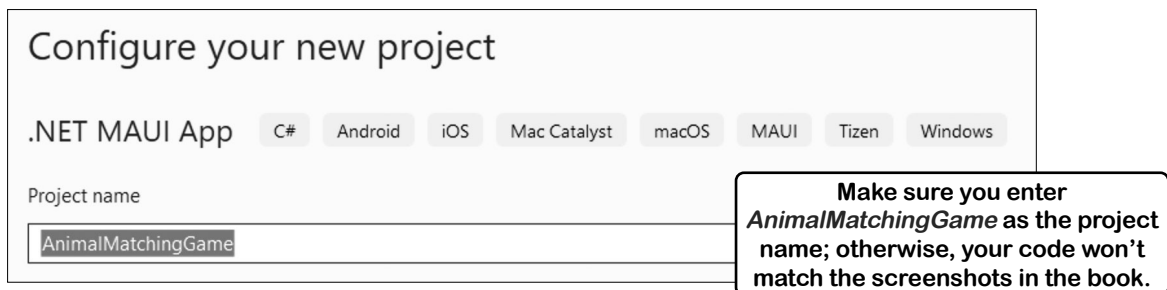
Create a .NET MAUI project in Visual Studio

You can create a .NET MAUI app in Visual Studio just like you did with the console app at the beginning of the chapter, using the “Create a new project” button displayed when you first open Visual Studio. If it’s already open, choose New >> Project (Ctrl+Shift+N) from the File menu to bring up the “Create a new project” window.



Choose the **.NET MAUI App project template** and click Next. Visual Studio will prompt you for a project name, just like it did when you created a Console App project.

Enter **AnimalMatchingGame** as the project name and click Next.



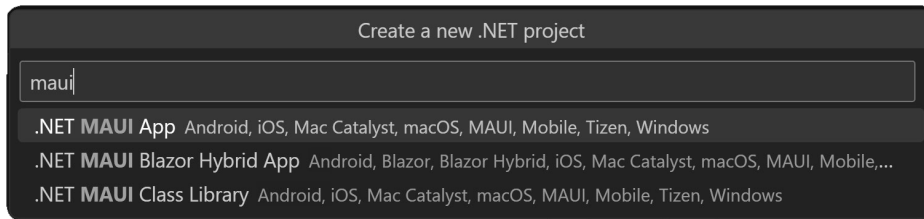
Finally, Visual Studio will ask you to choose a version of .NET—choose the latest version, just like you did when you created the Console App project. Then click the Create button to create your new .NET MAUI project.

Create a .NET MAUI project in Visual Studio Code

If you're using Visual Studio Code, creating a .NET MAUI project is really similar to creating the Console App project, just like you did at the beginning of the chapter. First, **close your current app** by choosing **File >> Close Folder** (Ctrl+K F or ⌘K F). It's *really important to close your folder*; otherwise, you'll add a new project to the same solution.

Next, create the .NET MAUI App project. Use Ctrl+Shift+P or ⇧⌘P to **open the Command Palette**. Choose the command **.NET: NEW Project** to create a new project. VSCode will prompt for the project type.

Choose the **.NET MAUI App** project type. You can type "MAUI" to filter the options.



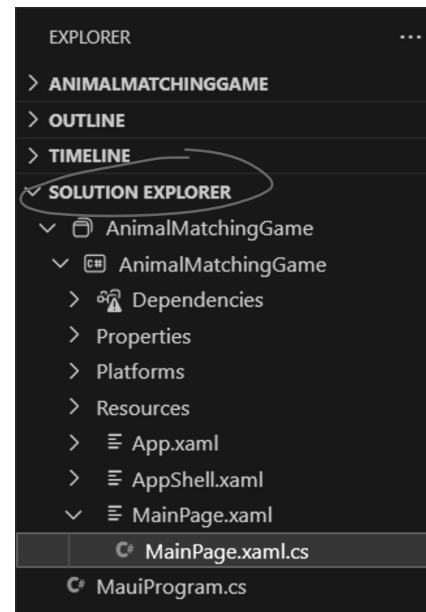
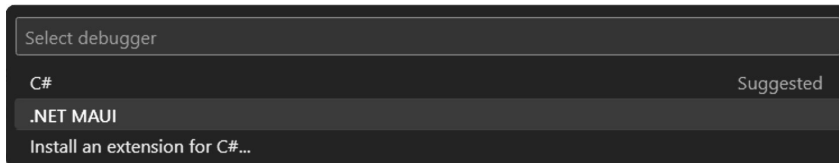
Make sure you enter **AnimalMatchingGame** as the project name; otherwise, your code won't match the screenshots in the book.

VSCode will ask you to give the project a name. **Name your project AnimalMatchingGame**. VSCode will prompt you for a directory. Choose the **default directory**. You should now see your project in the Solution Explorer at the bottom of the Explorer panel.

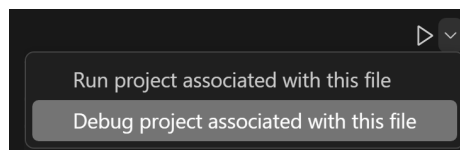
When it comes time to run your project, do the following—this is *different from running a Console App*:

1. Expand the Solution Explorer in the Explorer panel.
2. Expand the file *MainPage.xaml* to reveal MainPage.xaml.cs (it may be expanded already).
3. Click on MainPage.xaml.cs to select it.
4. Open the Command Palette (Ctrl+Shift+P or ⇧⌘P) and choose **Debug: Start Debugging**. You can also **open MainPage.xaml** and either **press F5** or choose Start Debugging from the Run menu.
5. VSCode may prompt you to select a debugger. Select **.NET MAUI**. Once you do that, your app should start running in a new window.

Expand the Solution Explorer and collapse all of the other sections of the Explorer window.

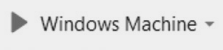


There's another way to run your MAUI app. Choose **Debug project associated with this file** from the dropdown next to the Run button at the upper right corner of the VSCode window.



The Solution Explorer section may be at the very bottom of the Explorer window.

Run your new .NET MAUI app

In Visual Studio: click  in the toolbar or choose **Start Debugging (F5)** from the Debug menu.

In Visual Studio Code: open `MainPage.xaml` and choose **Start Debugging (F5)** from the Run menu. If it prompts you to select a debugger, choose .NET MAUI from the list. On macOS you may see a prompt warning that `AnimalMatchingGame` is from an unidentified developer, and asking if you're sure you want to open it. **Click Open Anyway.**

The IDE will *build* your code, which means converting it to an executable program that your operating system can run. Then it will start your app:

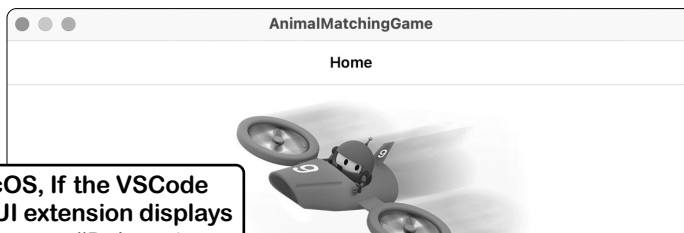
Do this!

When you see Do this! (or Now do this!, or Debug this!, etc.), go to Visual Studio and follow along. We'll tell you exactly what to do, and point out what to look for to get the most out of the example we show you.

These screenshots were made with .NET 9. If you're using a different version of .NET, the default MAUI app may look a little different.



In macOS, if the VSCode .NET MAUI extension displays the message "Debugging cancelled: Xcode not found," it means you need to *install or update Xcode*, a suite of development tools built by Apple. If you didn't install it when you set up Visual Studio Code and the C# extensions, you can install it from the App Store. Make sure you actually open it and *accept the Xcode license agreement*; otherwise, you may get an error when you try to debug a MAUI app in Visual Studio Code.



If you're using Windows and get a pop-up about setting your device to *developer mode*, click the link to go to settings for developers and toggle the "Developer mode" setting.

Stop your MAUI app

You can stop your app by **closing the app window**. You can also choose **Stop Debugging (Shift+F5)** from the Debug menu in Visual Studio or Run menu in VSCode, or **click the square Stop** button in the IDE's toolbar.

You can start or stop your app at any time. If there are syntax errors (like typos or invalid keywords) in the C# or XAML code, **the IDE won't be able to run the app.**

For tips on running your app, see <https://github.com/head-first-csharp/fifth-edition>.

MAUI apps work on all of your devices

MAUI is a **cross-platform framework** for building visual apps, which means the apps that you build can run on your Android and iOS devices. Many of the chapters in this book include .NET MAUI projects so you can learn to build more visual apps.

You can run MAUI apps on an Android device directly from Visual Studio. This page shows you how to set up an Android device so you can connect it to your computer and run your MAUI apps on it: <https://learn.microsoft.com/dotnet/maui/android/device/setup>

You can also run MAUI apps on your iOS device, but it requires a little more setup—and it costs money because you need to join the Apple Developer Program. This page walks you through the process: <https://learn.microsoft.com/dotnet/maui/ios/device-provisioning>



MAUI apps are designed with XAML

XAML (the X is pronounced like Z, and it rhymes with “camel”) is a markup language that you’ll use to build the user interfaces for your MAUI apps. XAML is based on XML (so if you’ve ever worked with HTML, you have a head start). Here’s an example of a XAML tag for a button:

```
<Button Text="Click" Clicked="Button_Click" />
```

This book is about learning C#, so we’ll give you just enough XAML so you can build great-looking MAUI apps—and we’ll make sure that you have a solid foundation for learning more.

Are you seeing errors or having problems in Visual Studio Code?

If you see an error window when you try to run your code—it may have a message like “Android SDK: Install required” or a warning about licenses—then there are some installation steps that you still need to do:

<https://learn.microsoft.com/dotnet/maui/get-started/installation?tabs=visual-studio-code>

Follow all of the steps on that page. Make sure you’ve installed all of the VSCode extensions, the .NET and .NET MAUI workloads, the Android SDK, and the latest XCode if you’re using a Mac. If you’re still running into problems, create a new .NET MAUI project and watch the Terminal window for error messages as soon as the project opens, and look for instructions on how to accept a license. Follow those instructions exactly. You may need to install the most recent version of OpenJDK first: <https://learn.microsoft.com/java/openjdk/download>

If you keep getting license errors on Windows, open the Command Palette and choose .NET MAUI: Configure Android and then Review Android Licenses to accept the licenses. You may need to do this while running VSCode as administrator. You can also choose “How to Configure Android” to see a web page with complete instructions.

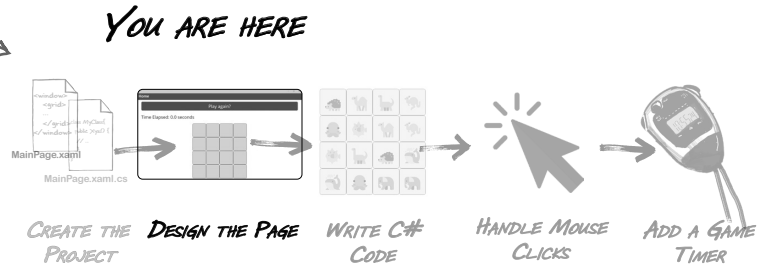
If you’re using a Mac, are you getting any of the following errors when you run your app: “No debug target available, skipping debugging,” an error about Android or iOS, or an error about prelaunch tasks terminating? Press ⌘⇧P to open the command palette, choose .NET MAUI: Pick macOS Device, and select your computer from the list, then open **MainPage.xaml** and press **F5** to run your app again.



If MAUI is still giving you problems, Microsoft has a page to help troubleshoot it: <https://learn.microsoft.com/dotnet/maui/troubleshooting>

think before you code

We'll include a "map" like this at the start of each of the sections of this project to help you keep track of the big picture.

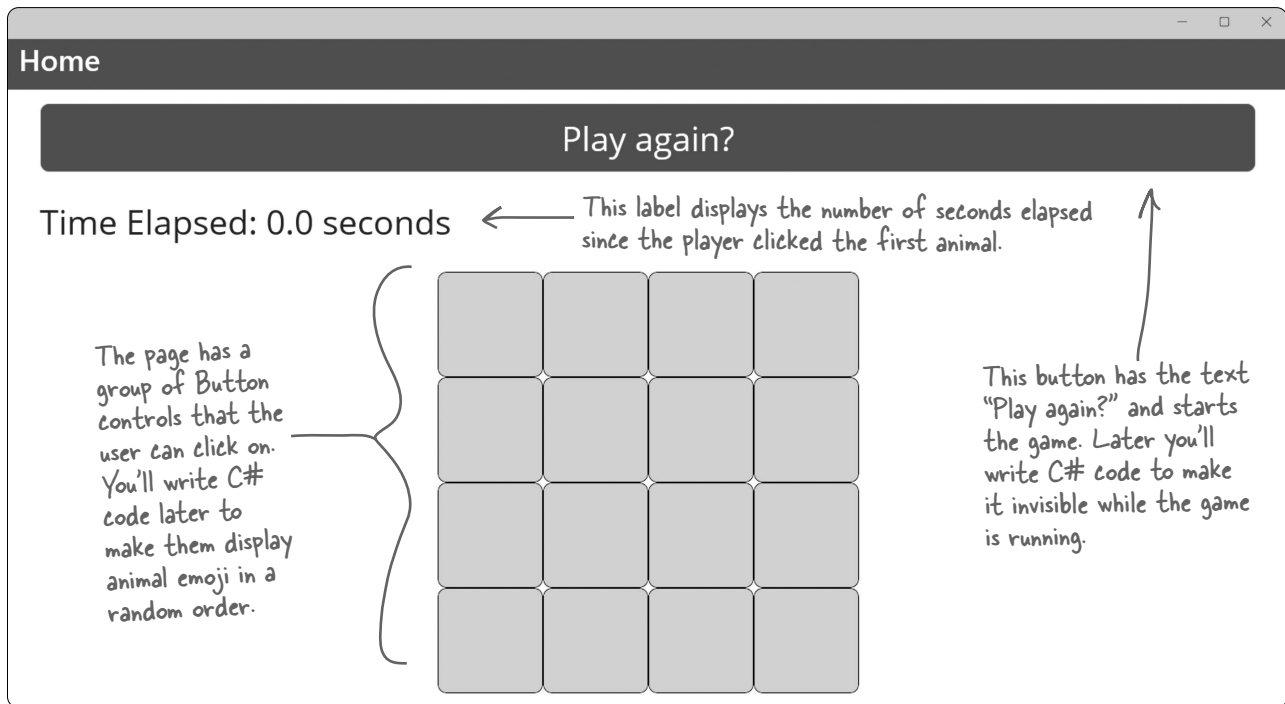


Here's the page that you'll build

When you start a project, the first thing you always want to do is take a few minutes to understand the big picture. What are you going to create? How will it work? Let's take a look at the page you're about to build.

When you open an app built with .NET MAUI, the first thing it shows you is a **page** that you interact with. That page uses **controls**, or visual widgets like buttons and labels, to create a user interface (or UI) that you can interact with. Here's the page that you're going to design:

You'll use XAML to lay out your page. A lot of C# developers consider XAML a core skill, and many C# jobs require you to know at least some XAML, so we wanted to make sure to include enough of it in this book to give you a good grounding in it.



Start editing your XAML code

The Solution Explorer lets you edit code files by double-clicking on them (or single-clicking in VSCode). We'll work with two files: *MainPage.xaml* (which contains your XAML code) and *MainPage.xaml.cs* (which has the C# code for your game). This is what it looks like in Visual Studio:

MainPage.xaml | **MainPage.xaml.cs**

New to .NET MAUI? Click here to learn more! | Don't show again

AnimalMatchingGame (net8.0-android)

1 <?xml version="1.0" encoding="...>

You can use these tabs to switch between files in your project.

Solution Explorer

Solution 'AnimalMatchingGame' (1 of 1 project)

- AnimalMatchingGame
 - Dependencies
 - Properties
 - Platforms
 - Resources
 - App.xaml
 - AppShell.xaml
 - MainPage.xaml
 - C# MainPage.xaml.cs
 - C# MauiProgram.cs

Here are the two files you'll edit in this project.

VSSideBar

New to .NET MAUI? Click here to learn more! | Don't show again

AnimalMatchingGame (net8.0-android)

1 <?xml version="1.0" encoding="...>

Code Editor

```

12 HeightRequest="185"
13 Aspect="AspectFit"
14 SemanticProperties.Description="dot net bot in a race car number eight" />
15
16 <Label
17 Text="Hello, World!"
18 Style="{StaticResource Headline}"
19 SemanticProperties.HeadingLevel="Level1" />
20
21 <Label
22 Text="Welcome to &#10;.NET Multi-platform App UI"
23 Style="{StaticResource SubHeadline}"
24 SemanticProperties.HeadingLevel="Level2"
25 SemanticProperties.Description="Welcome to dot net Multi platform App U I"
26 />
27
28 <Button
29 x:Name="CounterBtn"
30 Text="Click me"
31 SemanticProperties.Hint="Counts the number of times you click"
32 Clicked="OnCounterClicked"
33 HorizontalOptions="Fill" />
34
35 </VerticalStackLayout>
36 </ScrollView>
37 </ContentPage>
    
```

Callouts:

- Top Left:** "You can use these tabs to switch between files in your project."
- Top Right:** "If you close any of the files, you can open them again by double-clicking on them in the Solution Explorer. If you don't see it, you can open it by choosing Solution Explorer from the View menu."
- Bottom Left:** "VSCode looks a little different; the tabs work the same way. Just make sure you expand Solution Explorer in the Explorer panel. It helps to collapse the top section."
- Bottom Center:** "Make sure you expand MainPage.xaml in the Solution Explorer—that's the only way to see MainPage.xaml.cs."
- Bottom Right:** "Here are the two files you'll edit in this project."



You can always edit your XAML by hand instead of using the Toolbox or Properties windows.

When you use Visual Studio Code to edit the XAML code in *MainPage.xaml*, you may notice that it's missing some of the features we show in Visual Studio. At the time we're writing this, VSCode's .NET MAUI editor doesn't have a Toolbox or a Properties window.

Even if you're using Visual Studio, you might find that an element you need isn't in the Toolbox, or a property isn't in the Properties window. That's okay—the only thing those windows do is **add or change tags in your XAML code**. You get exactly the same XAML code whether you type it in or use the IDE's built-in tools.

In fact, it's often faster to edit your XAML by hand than to search the Toolbox or Properties windows. So even if we tell you to use the Toolbox or Properties window, **you can always type in the XAML code instead.**

Add the XAML for a Button and a Label

The first thing we'll do is design the page for the game. It will have 16 buttons to display the animal emoji, plus a "Play again?" button to restart the game when the player wins.



1 Delete everything between the opening and closing `VerticalStackLayout` tags.

XAML is a **tag-based markup language**. That means your XAML code uses **tags** to define everything that appears in your app. Here's an example of a tag—you can find it near the top of *MainPage.xaml*:

```
<ScrollView>
```

That's an **opening tag**. You can find its matching **closing tag** near the end of the file:

```
</ScrollView>
```

These tags add a **ScrollView control** to the page. If your app is in a window that's smaller than its contents, everything between the opening and closing tag can be scrolled up and down.

Find the opening `VerticalStackLayout` tag. It's on the next few lines of the file, and it looks like this:

```
<VerticalStackLayout
    Padding="30,0"
    Spacing="25">
```

Next, find the closing `VerticalStackLayout` tag:

```
</VerticalStackLayout>
```

Now **carefully delete all of the lines between those two tags**. The XAML code in your *MainPage.xaml* file should now look like this:

```
<?xml version="1.0" encoding="utf-8" ?>
<ContentPage xmlns="http://schemas.microsoft.com/dotnet/2021/maui"
    xmlns:x="http://schemas.microsoft.com/winfx/2009/xaml"
    x:Class="AnimalMatchingGame.MainPage">
```

```
<ScrollView>
```

```
<VerticalStackLayout
    Padding="30,0"
    Spacing="25">
```

```
</VerticalStackLayout>
</ScrollView>
```

```
</ContentPage>
```



If you're using a different version of .NET than we did, the XAML in the page may start out a little different. That's OK—you just need to get the XAML for your page to *exactly match* the XAML code below.

In the next step, you'll put your new XAML code right here, where you deleted the old code.



At the time we're writing this, the .NET MAUI extension for Visual Studio Code *does not* have a *Toolbox*. If you're using Visual Studio Code, you may not be able to do all of the fancy drag-and-drop XAML editing you get with Visual Studio, so you'll need to carefully type in all of the XAML line by line. But don't worry, your app will still work the same way.

2 Delete the C# code that goes with the XAML that you just deleted.

If you try to run your app right now, Visual Studio will give you an error message and refuse to run it, because the C# code depends on things you just deleted. **Expand MainPage.xaml in the Solution Explorer and open MainPage.xaml.cs** and find this code:

```
private void OnCounterClicked(object sender, EventArgs e)
```

Delete it, and the next 10 lines of code, up to and including the closing curly brace `}`. Be careful not to delete the final closing `}` at the end of the file. Then delete this line of code: `int count = 0;`

Your C# code should now look like this:

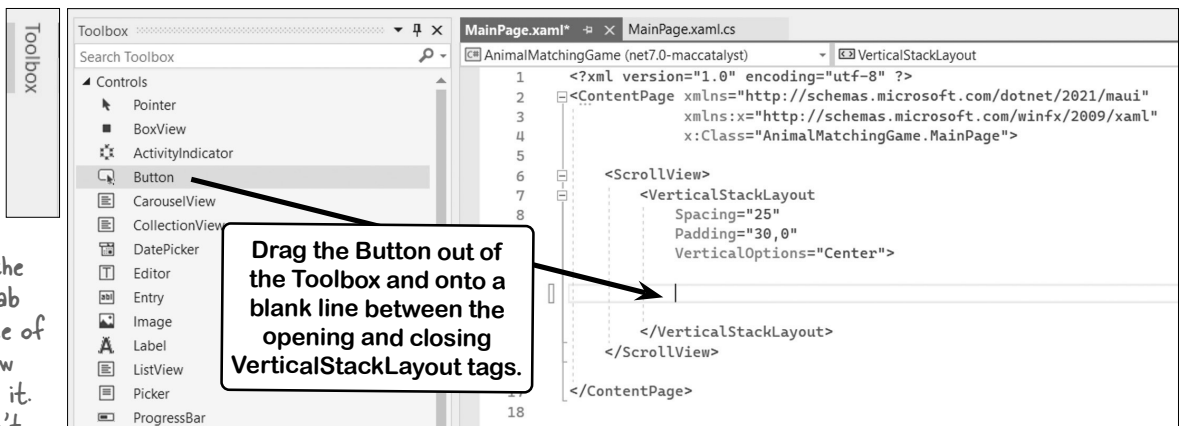
```
namespace AnimalMatchingGame;
{
    public partial class MainPage : ContentPage
    {
        public MainPage()
        {
            InitializeComponent();
        }
    }
}
```

You'll learn about classes and namespaces in Chapter 3.

Make sure you go back to the Solution Explorer and open MainPage.xaml.cs to edit the C# code. You may need to expand MainPage.xaml to see it.

3 Go back to MainPage.xaml and use the Toolbox to add the "Play Again?" button.

You'll be editing the XAML code again, so **switch back to the MainPage.xaml tab**. If you don't see the Toolbox panel, expand it by clicking the tab on the side of the window. **Add a few extra blank lines** where you deleted the code between the opening and closing `VerticalStackLayout` tags. Then **drag the Button out of the Toolbox** and drop it onto one of the lines that you added.



Click on the Toolbox tab on the side of the window to expand it. If you don't see it, choose Toolbox from the View menu. Click the pin button in the upper-right corner to keep it from collapsing.

You should now see a new Button tag between the `VerticalStackLayout` tags—it's OK if the spacing or indenting is a little different, because extra spaces or lines don't matter in XAML:

```
<VerticalStackLayout
    Padding="30,0"
    Spacing="25">
    <Button Text="" />
</VerticalStackLayout>
```

When you dragged the Button out of the toolbox and into your code, Visual Studio added this Button tag. If you're using VSCode, you may not have a Toolbox, so type this in exactly like it appears here.

add a button then add a label



If you're using Visual Studio Code, you may not have a Toolbox panel or Properties window. You'll need to type the XAML into the `MainPage.xaml` file so it exactly matches our code.

4

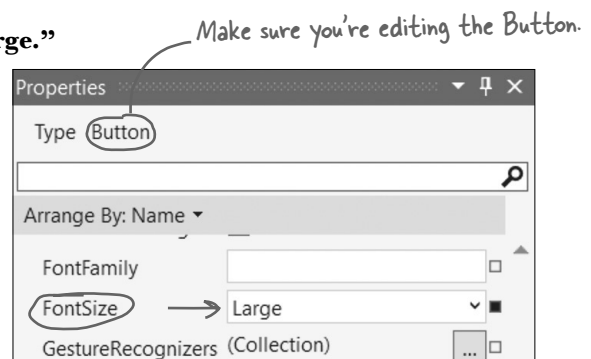
Add properties to the XAML tag for the “Play again?” button.

XAML tags have **properties** that let you set options to customize how they're displayed on the page. The **Properties window** in Visual Studio makes it easier to edit them.

Click on the code for the Button tag in `MainPage.xaml`, so your cursor is somewhere between the opening `<` and closing `>` angle brackets. Then look at the **Properties window**—it's usually docked in the lower-right corner of Visual Studio. If you don't see it, choose Properties or Properties Window from the View menu. Make sure it says “Type Button” at the top, so you know that you're editing the button.

Find the **Text** property and **set it to “Play again?”**

Then find the **FontSize** property and **set it to “Large.”**



When you're done editing the button, the XAML for it should look like this:

```
<Button Text="Play again?" FontSize="Large" />
```

The Button tag now has **Text and FontSize properties**.

5

Edit the XAML code by hand for your button to give it a name.

You can also edit XAML code by hand—for example, if you run into trouble with the Properties window, you could type the XAML directly into the editor. **You need to make sure that you copy all of the brackets, quotes, etc. exactly, otherwise your code won't run!**

In the next part of the project, you'll write C# code to make your “Play again?” button visible when the game is over, and invisible while the game is running. You'll give it a **name** that the C# code can use to tell it to show or hide itself.

Use the editor to **add an x:Name property** to give your button a name. It should look like this:

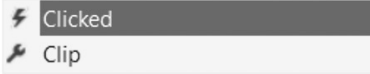
```
<Button x:Name="PlayAgainButton" Text="Play again?" FontSize="Large" />
```

XAML tags have properties that let you set options to customize how they're displayed on the page.

⑥ **Add an event handler so your button does something.**

When you click a button, it executes C# code called an **event handler**. Visual Studio makes it easy to add one. Place your mouse cursor just before the `/>` at the end of the Button tag and start typing **Clicked**. Visual Studio will pop up an IntelliSense window:

```
FontSize="Large" Click| />
```



Choose Clicked from the list and either click on it or press Enter. Visual Studio will then show you this:

```
FontSize="Large" Clicked="|" />
```



A XAML tag can be on a single line or split across multiple lines. Make sure you put the break in a space (not the space in "Play again").


Press Enter to add a new event handler. Your XAML tag should now look like this:

```
<Button x:Name="PlayAgainButton" Text="Play again?" FontSize="Large" Clicked="PlayAgainButton_Clicked" />
```

Switch to the MainPage.xaml.cs tab. You can see the code that Visual Studio added, which looks like this:

```
private void PlayAgainButton_Clicked(object sender, EventArgs e)
{
}

```

 *If you use IntelliSense to complete your line, it may not add the C# code—you'll need to open MainPage.xaml.cs and add this code to by hand. Your app will still work just fine.*

When you see an exercise, that's your chance to get some practice on your own. Make sure you do every exercise—they're an important part of the book. If an exercise is part of a project, then the project won't work until you get it right. But don't worry—we'll always give you the solution. And if you get stuck, it's always OK to peek at the solution!

Exercise

Add a Label control to your XAML page.

Go back to the screenshot of the game that shows the "Play again?" button. Notice how it also has text above the button that displays the time elapsed? That's a Label. It's up to you to add a tag for it. Here's what you'll do:

1. Switch to the MainPage.xaml tab.
2. Open the Toolbox and **drag a Label** into your XAML code. Make sure it gets added directly below the Button, just like you did in Step 3 when you were adding the Button.
3. Use the Properties window to set the **Text property to "Time Elapsed: 0.0 seconds"** and the **FontSize to "Large"** just like you did in Step 4 when you were adding the Button.
4. Edit the XAML code by hand and **set the x:Name to "TimeElapsed"** just like you did in Step 5 when you were adding the Button.

If you're using VSCode and don't have a Toolbox, skip straight to the Exercise Solution and carefully add the `<Label ... />` tag.

Exercise Solution

Add a Label control to your XAML page.

If you followed the steps in the exercise correctly, your XAML code in *MainPage.xaml* should now look like this:

```
<?xml version="1.0" encoding="utf-8" ?>
<ContentPage xmlns="http://schemas.microsoft.com/dotnet/2021/maui"
  xmlns:x="http://schemas.microsoft.com/winfx/2009/xaml"
  x:Class="AnimalMatchingGame.MainPage">

  <ScrollView>
    <VerticalStackLayout
      Padding="30,0"
      Spacing="25">

      <Button x:Name="PlayAgainButton" Text="Play again?" FontSize="Large"
        Clicked="PlayAgainButton_Clicked" />

      <Label x:Name="TimeElapsed" Text="Time Elapsed: 0.0 seconds"
        FontSize="Large" />

    </VerticalStackLayout>
  </ScrollView>

</ContentPage>
```

**It's OK if there are line breaks
between the properties in a tag, or if
the properties are in a different order.**

Here's the Label that you added in the exercise.
We added a line break between the Text and
FontSize properties, but you don't have to.

The C# code in *MainPage.xaml.cs* didn't get modified as part of the exercise, so it should still look like this—if you're using Visual Studio Code, you had to carefully type in the *PlayAgainButton_Clicked* method by hand:

```
namespace AnimalMatchingGame;
```

```
public partial class MainPage : ContentPage
{
    public MainPage()
    {
        InitializeComponent();
    }

    private void PlayAgainButton_Clicked(object sender, EventArgs e)
    {
    }
}
```

**Before you move on, make sure that
your XAML and C# code matches
ours *exactly*, and that your app looks
like our screenshot when you run it.**

If you run your app now, it should look like this. →

Press F5 to run your app again. In VSCode
you need to switch back to the XAML code
in *MainPage.xaml* and then press F5.



there are no
Dumb Questions

Q: What exactly is a “page” in a MAUI app?

A: A .NET MAUI app is usually built out of one or more **pages**, or individual screens that have different layouts and contain **controls** like labels and buttons. Some MAUI apps have multiple pages that let you navigate between them. Your Animal Matching Game app will just have a single page with 16 animal buttons, a “Play again?” button, and a label to show the elapsed time.

Q: So those buttons and labels are controls?

A: Yes. Everything you see on a MAUI page is a control—including the page itself, which is a `ContentPage` control. Some controls are dedicated to making your page look a certain way, like the `VerticalStackLayout` control that causes other controls to be stacked one on top of another. Others, like the `Button` and `Label` controls, are there to display some kind of widget that the user can see and interact with. We’ll talk more about controls in the next chapter.

Q: It looks like some controls contain others, like the `VerticalStackLayout` in my app contains `Button` and a `Label`. What’s going on there?

A: When you include layout control like `VerticalStackLayout` on your page, you can’t actually see it. Its whole purpose is to cause the other controls on the page to be displayed a certain way—in this case, to be stacked on top of each other. You need a way to tell MAUI which other controls on the page you want it to stack. To do that, you **nest** those other controls inside the `VerticalStackLayout` by including their tags between its opening `<VerticalStackLayout>` tag and its closing `</VerticalStackLayout>` tag.

Q: Why do some tags like `<ScrollView>` have a closing `</ScrollView>` tag, but others like `<Button>` don’t have one?

A: A `Button` control doesn’t need to have any other controls nested inside of it, so there’s no need for it to have a closing tag—instead, you can just end the tag with `/>` to make it **self-closing**.

These Brain Power boxes are here to give you something to think about. When you see one, don’t just go on to the next section. Take a few minutes and actually think about what you’re being asked. That will really help you get this material into your brain faster!



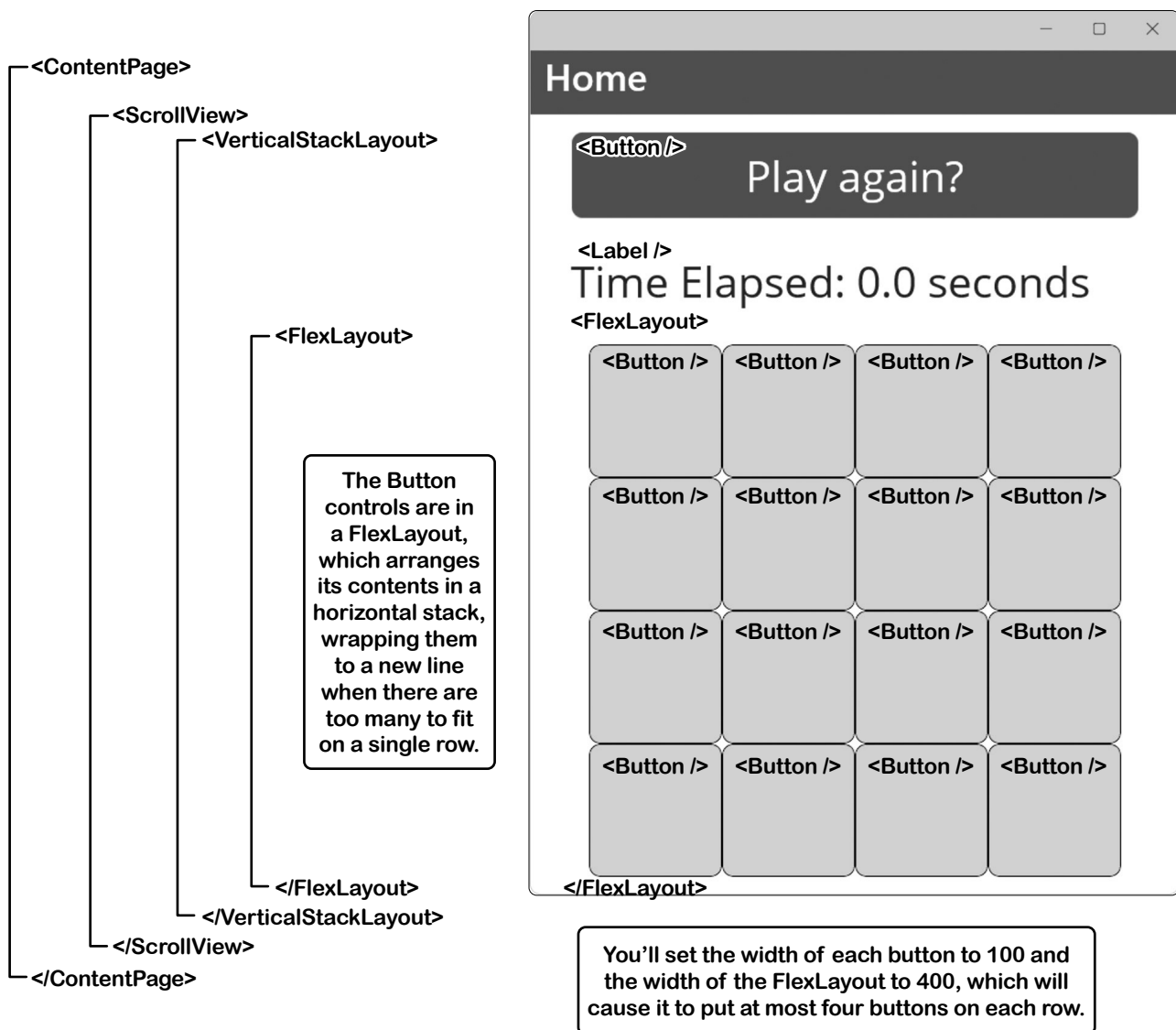
Brain Power

Your app is looking good so far, but now you need to add some buttons. How do you think you’ll do that? What do you think you’ll have to add to the XAML to get 16 buttons to be displayed in a layout with four rows of four buttons?

Use a FlexLayout to make a grid of animal buttons

The XAML for your page currently has three tags that determine its layout: there's a `ContentPage` tag on the outside that displays the whole view. It contains a `ScrollView`—everything nested between its start and end tags will scroll if it goes off the bottom of the page. Inside it is a `VerticalStackLayout`, which causes everything between its start and end tags to be stacked on top of each other in the order that they appear. Inside all of those tags are self-closing `Button` and `Label` tags.

The next thing you'll do is add a **FlexLayout**, which arranges anything inside of it in rows, wrapping them to the next row so they all fit inside its total width. You'll add 16 `Button` tags inside the `FlexLayout`. You'll get them to display in a 4x4 grid by setting the width of each button to 100 and the width of the `FlexLayout` to 400, so exactly four buttons will fit on each row.



Exercise

This looks like a big exercise! But don't worry, just take it step by step. We know you can do it! And remember, it's *not cheating* to look at the solution...in fact, seeing the solution is a great way to help you learn.

It's time to finish designing your page. In this exercise, you'll add a FlexLayout underneath the Label that you added in the last exercise. Next, you'll set its properties. Then you'll add a button. And finally, you'll copy the XAML for that button and paste it 15 more times, so you have a total of 16 buttons on your page. If you're using VSCode and don't have a Toolbox, just type the XAML exactly how it appears in the instructions instead of dragging it out of the Toolbox.

Add extra space for your FlexLayout control

Take a careful look at the screenshot that we just showed you. It shows you how the whole page works. Now go back to Visual Studio and look at the XAML for your page, and figure out exactly where the FlexLayout should go—just below the `<Label . . . />` tag.

Now put your cursor at that location and press Enter a few times to give yourself space to drag the FlexLayout.

Add the FlexLayout control just below the Label

1. Open the Toolbox and **drag a FlexLayout** into your XAML code. Make sure it gets added directly below the Label, into the extra space you just added. It will look like this: `<FlexLayout></FlexLayout>`.
2. Position your cursor between the `>` and `<` in the middle of the XAML you just added and **add several blank lines** between the opening and closing tags (you'll drag a button into that space later in the exercise).
3. Place your cursor directly on the opening `<FlexLayout>` tag. Make sure the Properties window shows that the type is FlexLayout.
4. Use the Properties window to set the **Wrap property** to "Wrap" and the **MaximumWidthRequest property** to "400."
5. Edit the XAML code by hand and **set the x:Name to "AnimalButtons"** just like you did in the last exercise.

Add the first Button inside the FlexLayout

1. Open the Toolbox and **drag a Button** into your XAML code. Make sure it gets added in the space that you added between the opening and closing tags of the FlexLayout. It will look like this: `<Button Text="" />`.
2. Place your cursor inside the **Button** tag. Make sure the Properties window shows that the type is Button.
3. Use the Properties window to set the Button's **HeightRequest property** to "100," the **WidthRequest property** to "100," and the **FontSize property** to "60." The dropdown in the Properties window won't have numbers—you can either type "60" into the window or choose Caption from the dropdown list to set the font size.
4. Edit the XAML for the button and **delete the Text property** by selecting it in the code editor and pressing Delete. Your cursor should now be inside the Button control.
5. Keep the cursor where it is and edit the XAML code by hand to **set the BackgroundColor property** to "LightBlue," **the BorderColor property** to "Black," and **the BorderWidth property** to "1." Visual Studio's IntelliSense pop-up will help you match the colors (but if you're using Visual Studio Code, you may not get a nice pop-up).
6. Add a **Clicked event handler**, just like you did with PlayAgainButton. **Choose <New Event Handler>** from the dropdown, so it creates a new event handler method in the C# code. Use the default name `Button_Clicked`.

Add the rest of the Buttons

If you're using VSCode, you might need to enter it by hand into `MainPage.xaml.cs`. It will be just like `PlayAgainButton_Clicked`, except without "PlayAgain" in the name.

Copy the `<Button . . . />` tag that you just added. Then **paste 15 identical tags below it**. You should now have a total of 16 identical Button tags inside a FlexLayout just below the Label. Run your app—it should match our screenshot.

The 16 Button tags should be identical. It's OK if the properties are in a different order.

build something great...fast!

Exercise Solution

```
HeightRequest="100" WidthRequest="100" FontSize="60" Clicked="Button_Clicked"/>
<Button BackgroundColor="LightBlue" BorderColor="Black" BorderWidth="1"
HeightRequest="100" WidthRequest="100" FontSize="60" Clicked="Button_Clicked"/>
<Button BackgroundColor="LightBlue" BorderColor="Black" BorderWidth="1"
HeightRequest="100" WidthRequest="100" FontSize="60" Clicked="Button_Clicked"/>
<Button BackgroundColor="LightBlue" BorderColor="Black" BorderWidth="1"
HeightRequest="100" WidthRequest="100" FontSize="60" Clicked="Button_Clicked"/>
<Button BackgroundColor="LightBlue" BorderColor="Black" BorderWidth="1"
HeightRequest="100" WidthRequest="100" FontSize="60" Clicked="Button_Clicked"/>
</FlexLayout>
```

```
</VerticalStackLayout>
</ScrollView>
```

```
</ContentPage>
```

Make sure **every button** has the `Clicked="Button_Clicked"` property. If the Clicked event handler has a different name, your C# code won't match ours. You can delete the Clicked property from all of the buttons, then *re-add it with the correct name*. Once you add the event handler, it will show up in the dropdown when you change the other buttons.

Here's the Button_Clicked event handler method in your *MainPage.xaml.cs* file:

```
private void Button_Clicked(object sender, EventArgs e)
{
}
}
```

↖ If you're using VSCode, you'll need to open *MainPage.xaml.cs* and add this event handler method by hand. Make sure it matches exactly!

I can check if my solution is right by comparing it with the screenshot. That makes it easier!

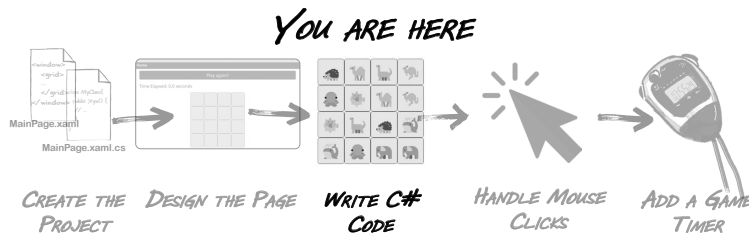


That's right!

If your app looks like this screenshot when you run it, you got things right. There's just one more thing you need to check: make sure that the `x:Name` properties match the ones in our solution **exactly**—the C# code you write will use them.



start writing C# code



Write C# code to add the animals to the buttons

You started this book to learn C#. You've done all the preparation: creating the project, and designing the page for your app. Now it's time to **get started writing C# code**.

We'll give you all of the code for this project, and show you exactly where it goes. But the goal is to **get you started learning C#**, so we'll also work with you to help you understand how it all works—and that will provide you with a solid foundation to start writing code on your own.

You'll add code that's run every time the "Play again?" button is clicked. Here's what it will do:

Make the animal buttons visible



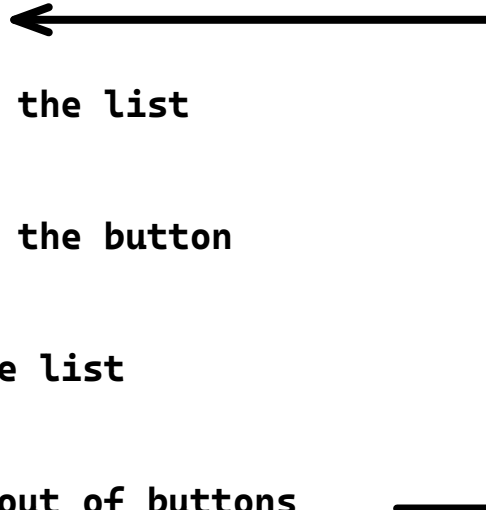
Make the "Play again?" button invisible



Create a list of 16 pairs of animal emoji



For each of the 16 buttons:



Pick a random animal from the list



Add that random animal to the button



Remove the animal from the list



Keep going until it runs out of buttons

Start editing the PlayAgainButton event handler method

When you were writing the XAML code for the “Play again?” button, you added an event handler:

```
FontSize="Large" Clicked="" />
```



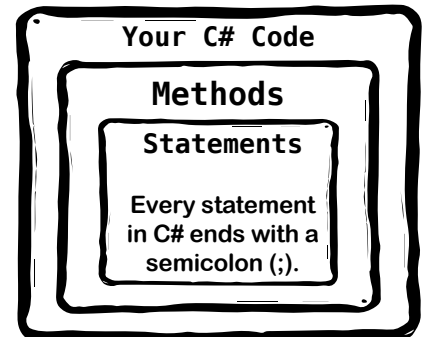
When you did this, Visual Studio added `Clicked="PlayAgainButton_Clicked"` to the XAML tag for the button. It also added this C# code to `MainPage.xaml.cs`:

```
private void PlayAgainButton_Clicked(object sender, EventArgs e)
{
}

```

That’s a **method**. C# code is made up of statements, or specific tasks that you’re telling your app to execute. Those statements are bundled into methods. Methods have a name—this method is named `PlayAgainButton_Clicked`.

Visual Studio generated that method for you automatically when you added the Clicked event handler to your XAML code to give you a place to add the statements that will tell it what to do when the “Play again?” button is clicked.



Add a C# statement to the event handler method

Place your cursor on the line between the opening `{` curly bracket and closing `}` curly bracket of the method. Then start typing the following line of code to make the animal buttons visible:

```
AnimalButtons.IsVisible = true;
```

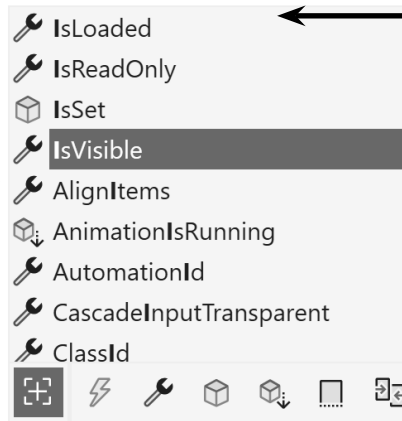
← Do this!

As you’re typing, you’ll see some of Visual Studio’s really powerful tools that help you write code:

```
private void PlayAgainButton_Clicked(object sender, EventArgs e)
{
    AnimalButtons.IsVisible = false;
}

```

This is an *IntelliSense* window. Visual Studio displays it as soon as you press the period key. It shows you options that you can use to add to the code you just wrote. If you choose `IsVisible`, it will auto-complete that part of the statement for you.



When you’re typing code, you may see Visual Studio giving you suggestions to complete the entire statement. This is a really powerful feature called *IntelliCode*. It uses an artificial intelligence system trained on millions of lines of code to give you suggestions—and more often than not, it seems to be able to read your mind!

↑ VSCode may not show you suggestions like this. It’s a feature of Visual Studio.

Add more statements to your event handler

When the player clicks the “Play again?” button, the app will display the animal buttons, hide the “Play again?” button, and then fill the animal buttons with eight pairs of animal emoji in a random order. You’re going to add statements to the `PlayAgainButton_Clicked` event handler method to do all that.

Do this!

1 Add a statement to make the “Play again?” button invisible.

Do you remember how you used the `x:Name` property in your XAML code to give names to the “Play again?” button and the `FlexLayout` that contains the 16 animal buttons? Take a minute and go back to that XAML code—you gave the `FlexLayout` the name “AnimalButtons,” and you just added a line of code that used that name.

You also used an `x:Name` to give the “Play again?” button the name “PlayAgainButton.” Now add a second line of code to your event handler method:

```
private void PlayAgainButton_Clicked(object sender, EventArgs e)
{
    AnimalButtons.IsVisible = true;
    PlayAgainButton.IsVisible = false;
}
```

Add this line of code right below the one you just added.

That statement turns the “Play again?” button invisible.

We made the code that's already in your files a lighter color to make it easier for you to see what to add.

2 Make the animal buttons invisible when the app starts.

Take a closer look at the first statement that you added to your event handler method. It makes the `FlexLayout` that contains the animal buttons visible. But wait a minute—it’s already visible! You saw it when you ran your app. Let’s do something about that.

Go back to the XAML code in `MainPage.xaml` and set the `IsVisible` property to “false”:

```
<FlexLayout x:Name="AnimalButtons" Wrap="Wrap"
            MaximumWidthRequest="400" IsVisible="false">
```

Did you notice that you’re **setting the same `IsVisible` property** in both the C# code and XAML? When the app starts, the `IsVisible="false"` in the XAML causes the page to display without the `FlexLayout` and its buttons. When you click the “Play Again?” button, the first line of code in its `Clicked` event handler method sets that property to true, causing the `FlexLayout` and its buttons to appear on the page.

Now your app will make the animal buttons invisible when it starts up. As soon as the player clicks the “Play again?” button to start the game, it will show the animal buttons and hide the “Play again?” button.

The properties on controls can be set in both XAML and C# code.

3 Run your app and make sure it works so far.

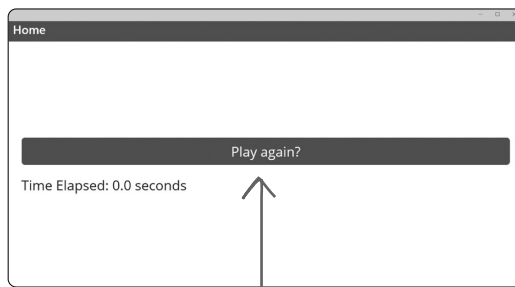
When you're writing code, you don't just write a complete app from beginning to end, and then run it to see if it works. That's not how it works at all! **Writing code is a creative process.** There are many, many ways to make your code do a specific thing, and in a lot of cases, the only way you can really be sure you're happy with it is to try writing it one way—and if you don't like it, change it.

Plus, it's easy to make **syntax errors** in your code. A syntax error means that you wrote something that isn't valid C# code, like using a keyword or symbol incorrectly or using a name that doesn't exist. For example, if you enter an extra `}` closing curly brace at the end of a method and then try to run it, Visual Studio will give you an error telling you that it can't **build** your code (which is what it does to turn your C# code into something that your computer can actually execute).

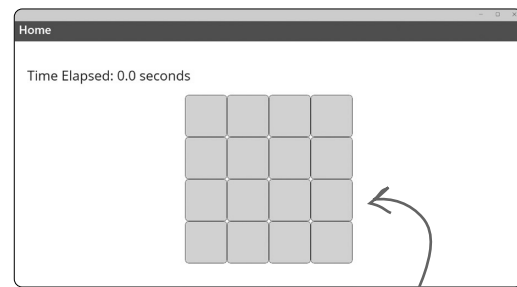
What does all that mean?

It means that you'll **run your apps all the time, over and over again.** And that's perfectly fine! It's absolutely OK to run your app after even a tiny change, just to see what that change did. The more comfortable you are running your app, the more you'll feel like you can experiment and make changes—and the more fun you'll have with it.

So go ahead and **run your app now.** Make sure it starts out with the “Play again?” button visible and the animal buttons invisible. Click the “Play again?” button and make sure it hides itself and shows the animal buttons. When you're done, close the app (or stop it from inside Visual Studio).



When you start the app, you'll see the “Play again?” button but no animal buttons.



Click the “Play again?” button to cause it to disappear and the animal buttons to appear.



When you enter your C# code, even tiny errors can make a big difference.

Some people say that you truly become a developer after the first time you've spent hours tracking down a misplaced period. Case matters: `AnimalButtons` is different from `animalButtons`. Extra commas, semicolons, parentheses, etc. can break your code—or, worse, change your code so that it still builds but does something different than what you want it to do. The IDE's **AI-assisted IntelliSense and IntelliCode features** can help you avoid those problems...but it can't do everything for you. It's up to you to make sure your code is right—and that it does what you expect it to do.

Add animals to your buttons

This game won't be much fun without animals to click on. Let's update the "Play again?" button's event handler method to set up the buttons with eight pairs of emoji positioned randomly on the buttons.

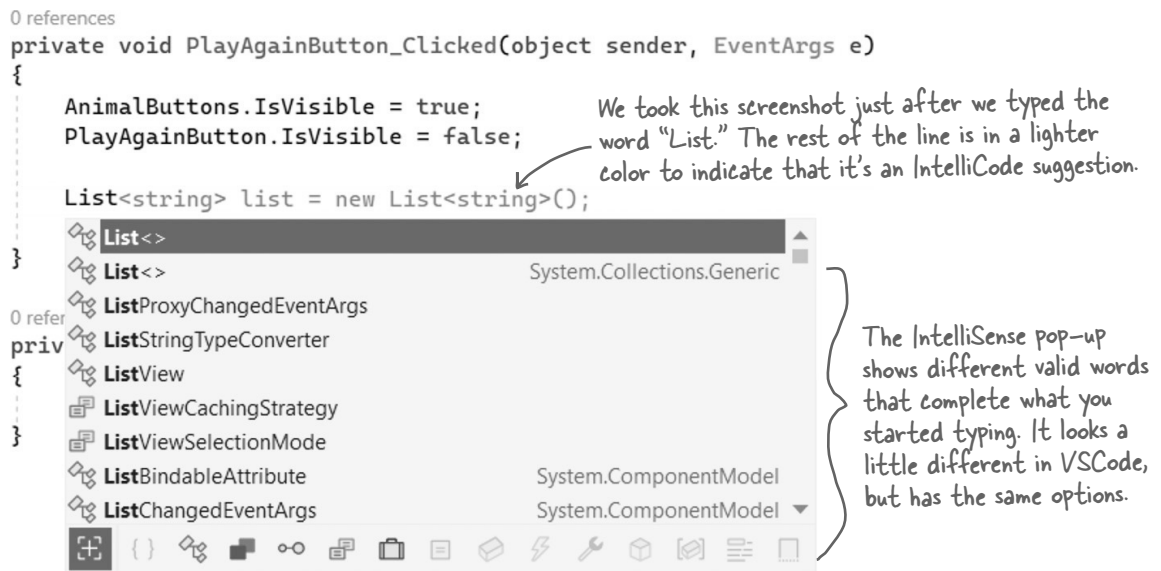
1 Start creating a List of animal emoji.

Your event handler method needs to start with eight pairs of emoji, so you're going to write a statement that creates them and stores them in something called a List (you'll learn a lot more about that in Chapter 8).

Switch back to MainPage.xaml.cs and start typing this line of code right *after* the statements that you just added—but *don't* end it with a semicolon, because that's not the end of the statement yet:

```
List<string> animalEmoji = [
```

While you're typing, you'll see IntelliSense windows pop up to help you enter that code. The text that you type will be in a bold color, followed by a **suggestion** generated by IntelliCode:



As soon as you typed the opening square bracket], Visual Studio added a matching one, placing your mouse cursor between the two brackets.:

```
List<string> animalEmoji = [ ] ← The mouse cursor should now be between the [ brackets ]
```

Press Enter, then add a semicolon to the end. Your PlayAgainButton_Clicked method should now look like this:

```
private void PlayAgainButton_Clicked(object sender, EventArgs e)
{
    AnimalButtons.IsVisible = true;
    PlayAgainButton.IsVisible = false;

    List<string> animalEmoji = [
]; ← Make sure you add the semicolon after the closing ] bracket.
```

Some people think the plural emoji is emoji, others think it's emojis. We went with emoji—but both ways are fine!

2 Add a pair of animal emoji to your list.

Your C# statement isn't done yet. Make sure your cursor is placed on the blank line you added between the brackets. Now let's add **eight pairs of animal emoji**. You can find emoji by going to your favorite emoji website (for example, <https://emojipedia.org/nature>) and copying individual emoji characters. Alternately...

If you're using Windows, use the **Windows emoji panel** (press Windows logo key + period). If you're using a Mac, use the **Character Viewer panel** (press the fn key, or Ctrl+⌘+Space on older Macs).

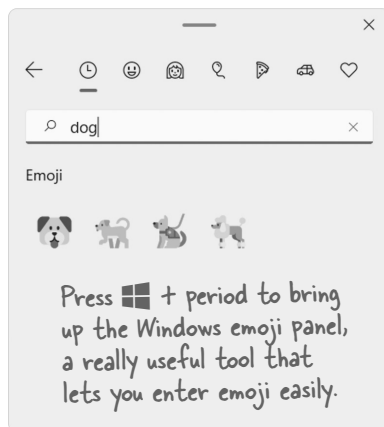
Go back to your code and add a double quote " then paste the character—we used an octopus—followed by another " and a comma, a space, another ", the same character again, and one more " and comma. You might notice Visual Studio helping you enter this list—for example, when you enter a double quote, it adds the closing quote.

Here's what your list should look like now:

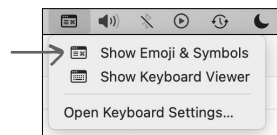
```
List<string> animalEmoji = [
    "🐙", "🐙",
];
```

How to enter emoji

If you're using Windows, use the **emoji panel** by pressing Windows logo key + period. Use the search box to search for a specific animal. When you find the emoji you want to enter, click on it to enter it as if you'd typed it.



If you're using a Mac, use the **Character Viewer panel**, by pressing Ctrl + ⌘ + space. Use the search box to search for a specific animal. When you find the emoji you want to enter, click on it to enter it as if you'd typed it.



You can also bring up the macOS Character Viewer using the Input menu in the menu bar. If you don't see the Input menu, open System Settings and search for "input menu"—there's an option that you can turn on to show the input menu in the menu bar.



3 Add the rest of the animal emoji pairs to your list.

Then do the same thing for seven more emoji so you end up with **eight pairs of animal emoji between the brackets**. We added a blowfish, elephant, whale, camel, brontosaurus, kangaroo, and porcupine—but you can add whatever animals (or other emoji!) that you want.

Add a `;` after the closing curly bracket. This is what your statement should look like now:

A List is a collection that stores a set of values in order. You'll learn all about collections in Chapters 8 and 9.

When you use `[brackets]` to specify a List, you're using a collection expression. Each animal in quotes is a separate string value, and values are separated by commas. You'll learn more about expressions in Chapter 8.

```
List<string> animalEmoji = [  
    "🐙", "🐙",  
    "🐘", "🐘",  
    "🐳", "🐳",  
    "🐪", "🐪",  
    "🦖", "🦖",  
    "🦘", "🦘",  
    "🦇", "🦇",  
    "🦇", "🦇",  
];
```

Be really careful with the quotes and commas. If you miss one, your code won't build.

Double-check that you're adding this code inside the `{ brackets }` after the `PlayAgainButton_Clicked` method, and not the `Button_Clicked` method.

4 Finish the method.

Add the rest of the code to add random animal emoji to the buttons—this code goes after the closing `];` at the end of the collection expression and before the `}` at the end of the method:

You'll learn more about loops in the next chapter.

```
foreach (var button in AnimalButtons.Children.OfType<Button>())  
{  
    int index = Random.Shared.Next(animalEmoji.Count);  
    string nextEmoji = animalEmoji[index];  
    button.Text = nextEmoji;  
    animalEmoji.RemoveAt(index);  
}
```

This is a *foreach loop*. It goes through a collection (like your list of emoji) and executes a set of statements for each item it finds.

Before you run your app, read through the code that you just added. It's OK if you don't understand everything that's going on with it yet. An important part of learning C# is starting to make the code make sense, and reading through it is a great way to do that.

Reading through C# code—even if you don't understand all of it yet—is a great way to make it all start to make sense.

5 Make sure your code matches ours.

Here's all of the C# code that you've added so far. We gave the parts that Visual Studio generated for you automatically a lighter color so you can see the code that you entered yourself.

```
namespace AnimalMatchingGame; ←
public partial class MainPage : ContentPage
{
    public MainPage()
    {
        InitializeComponent();
    }

    private void PlayAgainButton_Clicked(object sender, EventArgs e)
    {
        AnimalButtons.IsVisible = true;
        PlayAgainButton.IsVisible = false;

        List<string> animalEmoji = [
            "🐼", "🐼",
            "🐼", "🐼",
            "🐼", "🐼",
            "🐼", "🐼",
            "🐼", "🐼",
            "🐼", "🐼",
            "🐼", "🐼",
            "🐼", "🐼",
        ];

        foreach (var button in AnimalButtons.Children.OfType<Button>())
        {
            int index = Random.Shared.Next(animalEmoji.Count);
            string nextEmoji = animalEmoji[index];
            button.Text = nextEmoji;
            animalEmoji.RemoveAt(index);
        }

        private void Button_Clicked(object sender, EventArgs e)
        {
        }
    }
}
```

If you chose a different name for your project, this line will match that name.

You added this line to make the animal buttons invisible when the app first starts up.

Make sure there are exactly eight matching pairs of emoji. That's part of what makes the game work.

Visual Studio will automatically indent your code for you so it looks like ours. If you're using VSCode, press Alt-Shift-F or ⌘-Shift-F to automatically fix the indentation in your file.

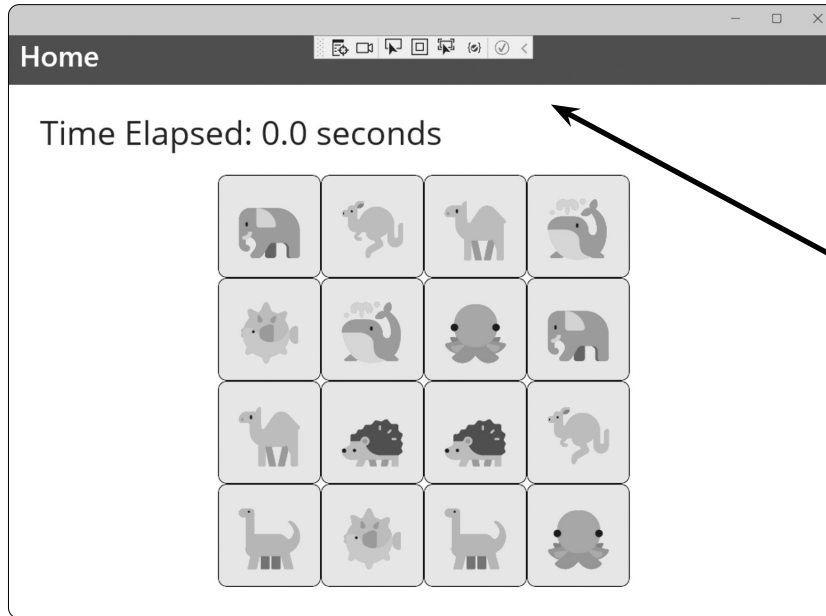
You just added this code to add the emoji to the buttons.

Visual Studio added this empty Button_Clicked event handler method when you added a Clicked property to the button that you copied and pasted. Make sure it's there! If you're using VSCode, you might need to carefully type it by hand if it didn't get added automatically.

you created it and it works

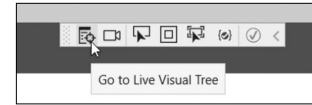
Run your app!

Run your app again. The first thing you'll see is the “Play again?” button. Click the button—you should now see eight pairs of animals in random positions:



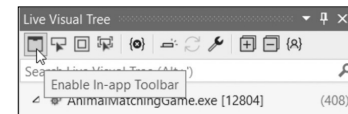
Stop it and run it again a few times. The animals should get reshuffled in a different order every time you click the “Play again?” button.

If you're using Visual Studio, you might see the *in-app toolbar* hovering at the top of the window:



We hid the in-app toolbar in our screenshots. You can keep yours visible or use the arrow at the right to collapse it.

You can also turn it off if you want (but you don't have to!). Click the first button in the runtime tools to bring up the Live Visual Tree panel in the IDE:



Then click the first button in the Live Visual Tree to enable or disable the in-app toolbar.



Wow, this game is already starting to look good!

You've set the stage for the next part that you'll add.

When you build a new game, you're not just writing code. You're also running a project. A really effective way to run a project is to build it in small increments, taking stock along the way to make sure things are going in a good direction. That way you have plenty of opportunities to change course.

This is a pencil-and-paper exercise. We included a lot of games and puzzles like this throughout the book. You should do all of them, because there's neuroscience evidence that writing things down is an effective way to get important concepts into your brain faster.



Who Does What?

C# statement	What it does
<pre>List<string> animalEmoji = ["🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼", "🐼",];</pre>	<p>Make the button display the selected emoji</p> <p>Find every button in the FlexLayout and repeat the statements between the { curly brackets } for each of them</p> <p>Make the "Play again?" button invisible</p> <p>Create a list of eight pairs of emoji</p>
<pre>foreach (var button in AnimalButtons.Children.OfType<Button>()) { animalEmoji.RemoveAt(index); button.Text = nextEmoji; string nextEmoji = animalEmoji[index]; AnimalButtons.IsVisible = true; int index = Random.Shared.Next(animalEmoji.Count); PlayAgainButton.IsVisible = false;</pre>	<p>Make the FlexLayout with the emoji buttons visible</p> <p>Pick a random number between 0 and the number of emoji left in the list and call it "index"</p> <p>Remove the chosen emoji from the list</p> <p>Use the random number called "index" to get a random emoji from the list</p>



I'm not sure about these "Sharpen your pencil" and matching exercises. Isn't it better to **just give me the code** to type into the IDE?

Working on your code comprehension skills will make you a better developer.

The pencil-and-paper exercises are **not optional**. They give your brain a different way to absorb the information. But they do something even more important: they give you opportunities to **make mistakes**. Making mistakes is a part of learning, and we've all made plenty of mistakes (you may even find one or two typos in this book!). Nobody writes perfect code the first time—really good programmers always assume that the code that they write today will probably need to change tomorrow. In fact, later in the book you'll learn about *refactoring*, a name for programming techniques that are all about improving your code after you've written it.

← We're serious—take the time to do the pencil-and-paper exercises. They're carefully designed to reinforce important concepts, and they're the fastest way to get the ideas in this book into your brain.

← We'll add bullet points like this to give a quick summary of many of the ideas and tools that you've seen so far.

Bullet Points

- Visual Studio is Microsoft's **IDE**—or *integrated development environment*—that simplifies and assists in editing and managing your C# code files.
- **Console apps** are cross-platform apps that use text for input and output.
- .NET **MAUI** (or .NET Multi-platform App UI) is a cross-platform framework for building visual apps in C#.
- MAUI user interfaces are designed in **XAML** (eXtensible Application Markup Language), an XML-based markup language that uses tags and properties to define controls in a user interface.
- MAUI apps are made up of **pages** that show **controls**.
- The FlexLayout control contains other controls and wraps them so they display on the page.
- The IDE's Properties window makes it easy to edit the properties of your controls like the text or font size.
- C# is made up of **statements** grouped into **methods**.
- An **event handler method** gets executed when specific events—like button clicks—happen.
- Visual Studio's AI-assisted **IntelliSense** and **IntelliCode** help you enter code more quickly.



*My project has a lot of code already! Wouldn't it be dreamy if there was an easy way for me to save everything I've done someplace where I can **save my code, share it, and always find it** any time I want?*

You can use Git to save all of your code, and Visual Studio will help make it easy.

You're going to write a lot of code in this book! Wouldn't it be great if there was a convenient place to put that code so you can always go back to it?

We bet that you'll write some apps that you really like, and you'll want to share them with your friends so they can see the great things you've built.

Do you have a desktop and a laptop? A computer at home and at an office? Wouldn't it be great if you could start a project on one computer, then finish it on another one?

Imagine you're working on a project. You've spent hours getting the code right, and you're really happy with it. Then you make a few changes, and...oh no! Something went completely wrong, your code is broken, and you don't remember exactly what you changed. It would be great if you could see a history of all the changes you made, right?

Git can help you do all of those things!

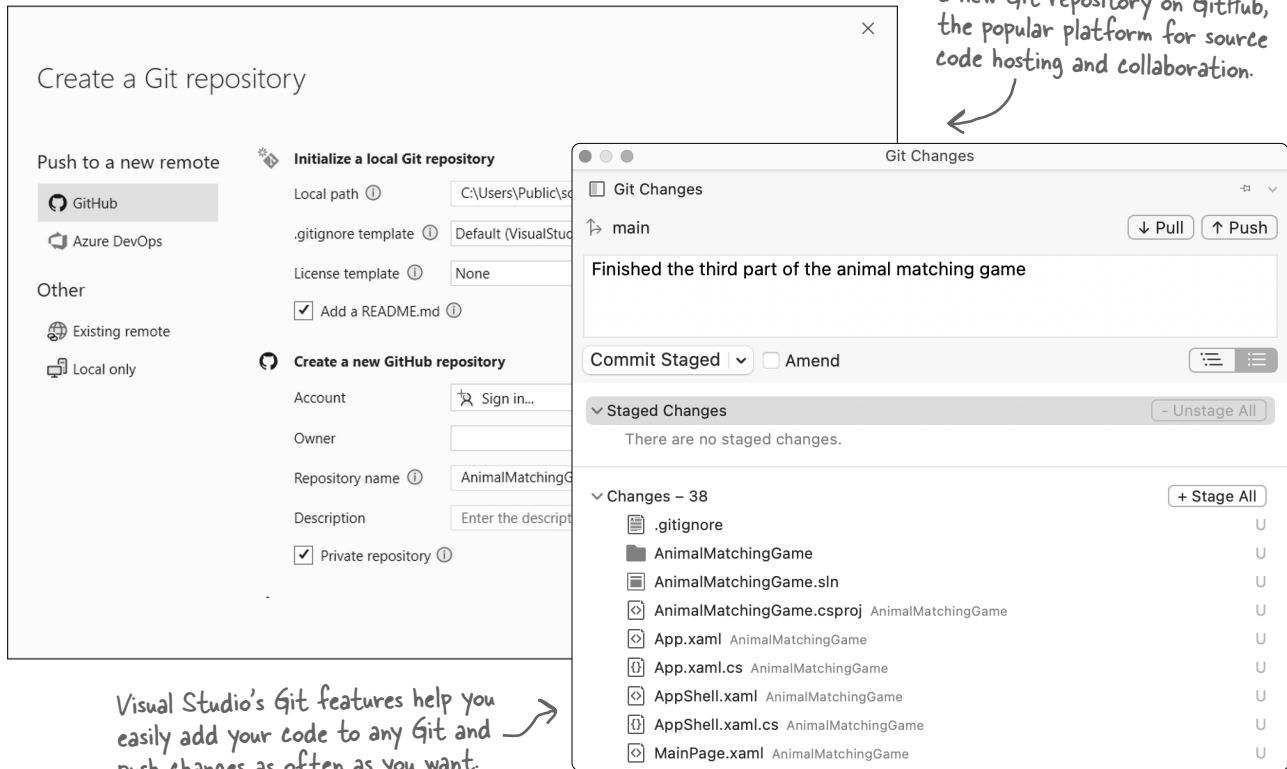
Here are just a few things Git can do for you

- ★ It can save your files somewhere that you can access them from anywhere, any time.
- ★ It lets you save snapshots of your work so you can go back and see exactly what changed.
- ★ It lets you share your code with anyone (or keep it private!).
- ★ It lets a group of people collaborate on a project together—so if you're learning C# with your friends, you can all work on code together.

Visual Studio makes it easy to use Git

Git is a really powerful and flexible tool that can help you save, manage, and share the code and files for all of your projects. It can also be complex and confusing at times! Luckily, Visual Studio has **built-in Git support** that takes care of the complexity. It helps you with Git, so you can concentrate on your code.

Visual Studio can help you create a new Git repository on GitHub, the popular platform for source code hosting and collaboration.

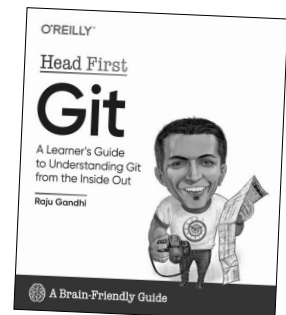


Visual Studio's Git features help you easily add your code to any Git and push changes as often as you want.

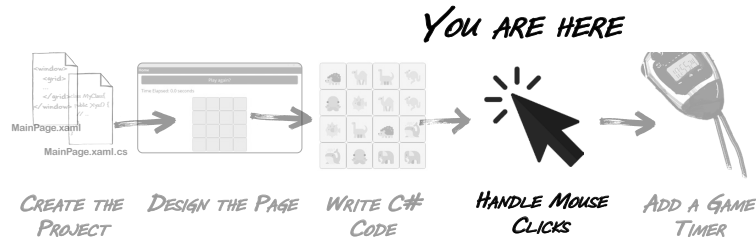
We recommend that you create a GitHub account and use it to save the code for each of the projects in this book. That will make it easy for you to go back and revisit past projects any time!

Our free Head First C# Guide to Git PDF gives you a simple, step-by-step guide to saving your code in Git with Visual Studio. Download it from <https://github.com/head-first-csharp/fifth-edition>.

We'll give you everything you need to use Visual Studio to save and share your projects. But there is a lot more that you can do with Git, especially if you're working with large teams! If you're fascinated by what you see and want to do a deep dive into Git, check out *Head First Git* by Raju Gandhi.

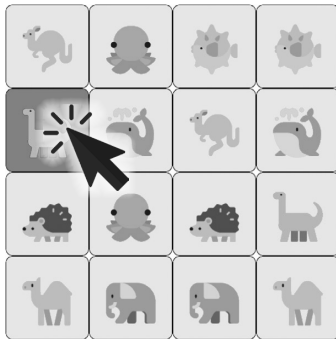


how mouse clicks will work



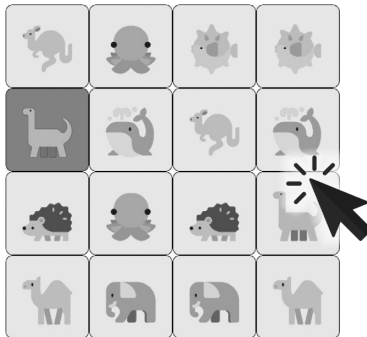
Add C# code to handle mouse clicks

You've got buttons with random animal emoji. Now you need them to do something when the player clicks them. Here's how it will work:



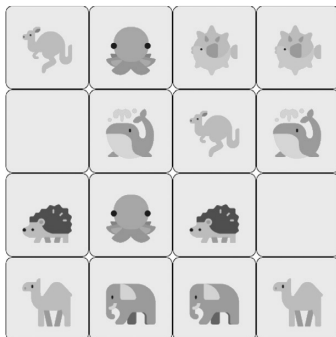
The player clicks the first button.

The player clicks buttons in pairs. When they click the first button, the game keeps track of that particular button's animal. The button that the player clicked changes color, so they can see what animal they clicked on.



The player clicks the second button.

The game looks at the animal on the second button and compares it against the first one they clicked on. The game compares its animal against the animal on the button that it kept track of from the first click.



The game checks for a match.

If the animals **match**, the game goes through all of the emoji in its list of shuffled animal emoji. It finds any emoji in the list that match the animal pair the player found and replaces them with blanks.

If the animals **don't match**, the game doesn't do anything.

In **either case**, it resets its last animal found so it can do the whole thing over for the next click.

The game repeats this until all eight pairs of animals are matched.

Sharpen your pencil



When you added the Clicked event handler to your animal button, Visual Studio **automatically added a method called Button_Clicked** to *MainPage.xaml.cs*. Here's the code that will go into that method. Before you add this code to your app, read through it and try to figure out what it does.

We've asked you a few questions about what the code does. Try writing down the answers. **It's OK if you're not 100% right!** The goal is to start training your brain to recognize C# as something you can read and make sense of.

```
Button lastClicked;
bool findingMatch = false;
int matchesFound;
```

1. What does `matchesFound` do?

```
private void Button_Clicked(object sender, EventArgs e)
{
    if (sender is Button buttonClicked)
    {
        if (!string.IsNullOrEmpty(buttonClicked.Text) && (findingMatch == false))
        {
            buttonClicked.BackgroundColor = Colors.Red;
            lastClicked = buttonClicked;
            findingMatch = true;
        }
        else
        {
            if ((buttonClicked != lastClicked) && (buttonClicked.Text == lastClicked.Text))
            {
                matchesFound++;
                lastClicked.Text = " ";
                buttonClicked.Text = " ";
            }
            lastClicked.BackgroundColor = Colors.LightBlue;
            buttonClicked.BackgroundColor = Colors.LightBlue;
            findingMatch = false;
        }
    }

    if (matchesFound == 8)
    {
        matchesFound = 0;
        AnimalButtons.IsVisible = false;
        PlayAgainButton.IsVisible = true;
    }
}
```

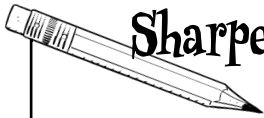
2. What do these three lines of code do?

That's a double quote followed by a space and another double quote.

3. What does this block of code do?

4. What do the last six lines of the method starting with `if (matchesFound == 8)` and going to the end do?

this code runs when the user clicks



Sharpen your pencil Solution

We've asked you a few questions about what the code does. Try writing down the answers. *It's OK if you're not 100% right!* The goal is to start training your brain to recognize C# as something you can read and make sense of.

```
Button lastClicked;  
bool findingMatch = false;  
int matchesFound;
```

1. What does `matchesFound` do?
It keeps track of the number of pairs of animals the player found, so the game can end when they found all 8 pairs.

```
private void Button_Clicked(object sender, EventArgs e)  
{
```

```
    if (sender is Button buttonClicked)
```

```
    {  
        if (!string.IsNullOrEmpty(buttonClicked.Text) && (findingMatch == false))
```

```
        {  
            buttonClicked.BackgroundColor = Colors.Red;  
            lastClicked = buttonClicked;  
            findingMatch = true;
```

2. What do these three lines of code do?
These lines are run when the player clicks the first button of a potential match to change its color to red and keep track of it.

```
        }  
    }  
    else
```

```
    {  
        if ((buttonClicked != lastClicked) && (buttonClicked.Text == lastClicked.Text))
```

```
        {  
            matchesFound++;  
            lastClicked.Text = " ";  
            buttonClicked.Text = " ";
```

3. What does this block of code do?
This block of code is run when the player clicks on the second button in the pair. If the animals match, it adds one to `matchesFound` and blanks out the animals on both buttons. It also resets the color of the first button back and gets set for the player to click the first button in a pair again.

```
        }  
        lastClicked.BackgroundColor = Colors.LightBlue;  
        buttonClicked.BackgroundColor = Colors.LightBlue;  
        findingMatch = false;
```

```
    }  
}
```

```
if (matchesFound == 8)
```

```
{  
    matchesFound = 0;  
    AnimalButtons.IsVisible = false;  
    PlayAgainButton.IsVisible = true;  
}
```

```
}
```

4. What do the last six lines of the method starting with `if (matchesFound == 8)` and going to the end do?
If `matchesFound` equals 8, the player found all 8 pairs of animals. When that happens, these lines reset the game by setting `matchesFound` back to zero, hiding the animal buttons, and showing the "Play again?" button so the player can start a new game by clicking the "Play again?" button.

Do you see a warning in the Error List window about a non-nullable field? Your code will still run even when you see green warnings (unlike red errors, which mean your code can't run). But you should still pay attention to warnings! Don't worry about this warning for now—you'll learn about what it is and how to fix it in Chapter 11.

Enter the code for the event handler

Did you do the “Sharpen your pencil” exercise? If not, take a few minutes and do it—you may not understand 100% of the code in the `Button_Clicked` event handler method yet, but you should at least have a basic sense of what’s going on. And, more importantly, you’ve had a chance to look at it closely enough so that it should be familiar.

That familiarity will make it easier to **use the IDE to type the code into the method**. Stop your app if it’s running—close the window or choose Stop Debugging (Shift+F5) from the Debug or Run menu—then edit `MainPage.xaml.cs`, find the `Button_Clicked` event handler method that Visual Studio added for you, and click on the line between its opening `{` and closing `}` curly brackets.

Now **start typing the code from the “Sharpen” solution** line by line. If you haven’t used an IDE like Visual Studio or VSCode to write code, it may be a little weird seeing its IntelliSense and IntelliCode suggestions pop up. Use them if you can—the more you get used to them, the faster and easier it will be to write code later on in the book.

You need to be really careful when you’re entering code, because if your opening parentheses or brackets don’t have matches, or if you miss a semicolon at the end of a statement, your code won’t build. Luckily, Visual Studio has a lot of features to help you write code that builds:



- ★ When you enter `if` it automatically adds the opening and closing parentheses `()` so you don’t accidentally leave them out.
- ★ If you put your cursor in front of an opening parenthesis or bracket, it will highlight the closing one so you can easily see its match.
- ★ A lot of the time, when you enter code that has problems—like writing `matchesFnd` instead of `matchesFound`, for example—it will often point out the error by drawing a red squiggly line underneath it.



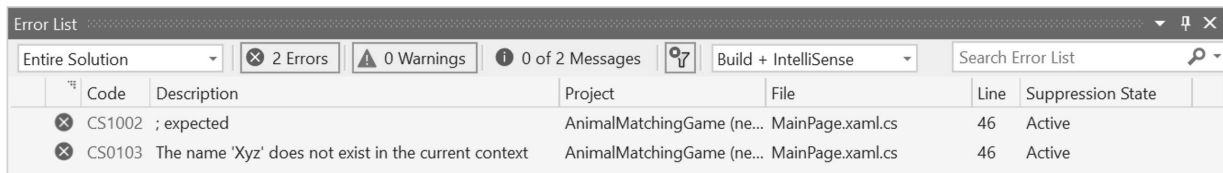
IDE Tip: The Error List

An operating system like Windows, macOS, Android, or iOS can’t run C# code. That’s why Visual Studio has to **build** your code, or turn it into a **binary** (a file that the operating system can run). Let’s do an experiment and **break your code**.

Go to the first line of code in your `Button_Clicked` method. Press Enter twice, then add this on its own line: `XYZ`


Check the bottom of the code editor again—you’ll see an icon that looks like this:  or . If you don’t see the icon, choose Build Solution from the Build menu to tell Visual Studio to try to build your code.

Click the icon (or choose Error List from the View menu) to open the Error List window. You’ll see two errors in the window (if you’re using a Mac it’s called Errors and not Error List, and it looks a little different, but it displays the same information):



Code	Description	Project	File	Line	Suppression State
CS1002	; expected	AnimalMatchingGame (ne...	MainPage.xaml.cs	46	Active
CS0103	The name 'Xyz' does not exist in the current context	AnimalMatchingGame (ne...	MainPage.xaml.cs	46	Active

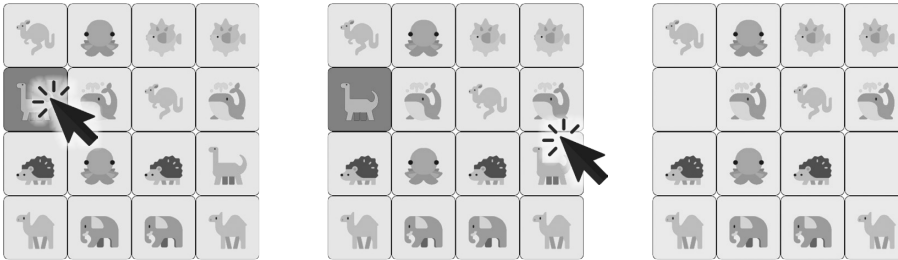
Visual Studio displayed these errors because `XYZ` is not valid C# code, and the errors prevent it from building your app. Your code won’t run with those errors, so go ahead and delete the `XYZ` line that you added and build your app again.

If there are no other errors in your code, the Error List should be empty, and you’ll see an icon that looks like this at the bottom of the Visual Studio window:  No issues found or  Build successful.—that tells you that your app builds.

now your game does more

Run your app and find all the pairs

Try running your app. If you entered all of the code correctly, it should start up and show you the “Play again?” button. Click the button to see a random list of animals. Then click each pair of animals one by one—each pair will disappear after you click it. Once you click the last pair of animals, the buttons will disappear and you’ll see the “Play again?” button again.



Try experimenting with your app. Click mismatched pairs. Click in the window but outside the buttons. Click on the “Time elapsed” label. Click an empty button. Is your app working?

Uh-oh—there’s a bug in your code

If you typed in all of the code correctly, you may have noticed a problem. Start your app, click the “Play again?” button to show the random animals, and click on a pair to make the animals disappear from their buttons. Now **click the one of the blank buttons, then the other—and repeat that seven times**. Wait, what happened? Did the animal buttons disappear and the “Play again?” button appear, as if you’d won the game? That’s not supposed to happen! Your game has a bug.

Don’t worry, this bug is not your fault!

We left that bug in your code on purpose. You’re going to be writing a lot of code throughout this book. Every chapter has several projects for you to work on...and there are opportunities for bugs in every one of those projects. Finding and fixing bugs is a normal and healthy part of writing code—and a really valuable skill for you to practice.

When you find a bug, you need to sleuth it out

Every bug is different. Code can break in many different ways. But there’s one thing all bugs have common: every one of them **is caused by a problem in the code**. So when there’s a bug, your job is to figure out what’s causing it, because you can’t fix the problem until you know why it’s happening.

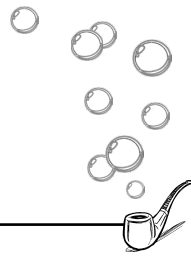
If you’ve ever read a mystery novel or watched a detective show, you know that to solve a mystery, you need to **find the culprit**. So let’s do that right now. It’s time to put on your Sherlock Holmes cap, grab your magnifying glass, and **sleuth out what’s causing the bug**.

If your game doesn’t work the way it should or you don’t see the bug on this page, go back and check the code you entered against the code in the book. It’s really easy to overlook a typo. Finding those issues is a good use of your time, because spotting errors in your code is a really good developer skill to work on.

Every bug is caused by a problem in the code, so the first step in fixing a bug is figuring out what’s causing it.



Finding and fixing bugs is one part typing, nine parts thinking... and 100% guaranteed to make you a better developer. That's what these "Sleuth it Out" sections are all about.



Sleuth it Out

The Case of the Unexpected Match

You've probably heard the word "bug" before.

You might have even said something like this to your friends at some point in the past: "That game is really buggy, it has so many glitches." Every bug has an explanation, and everything in your program happens for a reason...but not every bug is easy to track down. That's why we'll include tips for sleuthing out bugs throughout the book, starting with this "Sleuth it Out" section.

Every bug has a culprit.

Bugs are weird. They're what happens when your code does something you didn't expect it to do.

But bugs are also normal. Every developer spends time finding and fixing bugs. It's a normal part of writing code. You're going to write code that doesn't do what you expect it to. And when you do, the first thing you need to do is **figure out what's causing the bug**.



The first step in finding a bug is thinking about what might have caused it.

Sherlock Holmes once said, "Crime is common. Logic is rare. Therefore it is upon the logic rather than upon the crime that you should dwell." That's great advice for figuring out what caused a bug. Don't get frustrated because your app doesn't do what you want (that's dwelling on the crime!). Instead, think about the logic of the situation. So let's look at the code and figure out what's going on.

Read the code carefully and search for clues.

We know that all of the code for handling mouse clicks is in the Button_Clicked event handler that you just added. So let's go back to the code and see if we can find clues about what went wrong.

Luckily, **you did that "Sharpen your pencil" exercise**. You looked closely at the code in the Button_Clicked event handler method to understand it. (If you haven't done that exercise yet, go back and do it now!)

Based on what we found in the "Sharpen your pencil" exercise, we already know a few things about the code:

- The event handler uses matchesFound to keep track of the number of pairs of animals the player found, so the game can end when they find all eight pairs.
- There's a part of the event handler that checks if the animals on the two buttons that the player clicked on match each other. If they do match, it adds one to matchesFound and blanks out both buttons.
- If matchesFound equals 8, the player found all 8 pairs of animals. There's code at the end of the event handler that checks to see if matchesFound is equal to 8, and if that's true it resets the game.

Those are the important clues that will help us find and fix the bug. Before you go on, can you sleuth out what's causing the game to end early if you keep clicking a button that's already been cleared?



Why did the bug happen?

Let's think about those three clues for a minute. Here's what we know:

- The game uses `matchesFound` to keep track of the number of pairs of animals the player found.
- If the player clicks on a pair, the game increases `matchesFound` by 1 and blanks out the buttons the player clicked on.
- When `matchesFound` reaches 8, the game resets itself.

So what are these clues telling us? There's one conclusion that we can draw from these clues:

Somehow `matchesFound` is being increased by 1 when the player clicks on a button that's already blanked out.

Which means we have a starting point: the code that increases `matchesFound` by 1.

Go back to the scene of the crime

Here's the part of the code that increases `matchesFound` – the specific line that does that is in boldface:

```
if ((buttonClicked != lastClicked) && (buttonClicked.Text == lastClicked.Text))
{
    matchesFound++;
    lastClicked.Text = " ";
    buttonClicked.Text = " ";
}
```

This statement uses the `++` operator to increase the value of `matchesFound` by 1. You'll learn about `++` and other operators in the next chapter.

The first line of code in the statements that we just showed you is an **if statement**, checks if something is true, and if it is then it executes statements. In this case, if the player clicked a different button than the first one in the pair (that's what "`buttonClicked != lastClicked`" checks for) and if the animals on those two buttons match ("`buttonClicked.Text == lastClicked.Text`"), it increases `matchesFound` by 1 and blanks out both buttons.

This is where things went wrong—which means it's also where we can fix the bug. We just need to find a way to keep `matchesFound` from getting increased by 1 **if the player clicked a button that's already blank**.

We found the culprit, so now we can fix the bug.

Position your cursor between the last two closing parentheses `)` in the `if` statement and press Enter to add a line. Then enter the following code: `&& (!String.IsNullOrEmpty(buttonClicked.Text))`

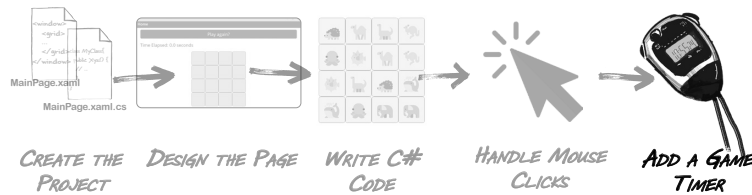
Here's what your code should now look like:

```
if ((buttonClicked != lastClicked) && (buttonClicked.Text == lastClicked.Text)
    && (!String.IsNullOrEmpty(buttonClicked.Text)))
{
    matchesFound++;
    lastClicked.Text = " ";
    buttonClicked.Text = " ";
}
```

Adding this code to your "if" statement causes it to make sure the button that the player clicked on is not blank before adding 1 to `matchesFound`.

Once you've edited the `if` statement, run your app again. Now the bug should be fixed.

YOU ARE HERE



Finish the game by adding a timer

Our animal match game will be more exciting if players can try to beat their best time. We'll add a **timer** that "ticks" after a fixed interval by repeatedly calling a method.

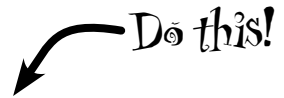
Let's add some excitement to the game! The time elapsed since the game started will appear at the bottom of the window, constantly going up, and only stopping after the last animal is matched.



Timers "tick" every time interval by calling methods over and over again. You'll use a timer that starts when the player starts the game and ends when the last animal is matched.

Add a timer to your game's code

In this last part of your project, you'll add a timer to your game to make it more exciting. It will keep track of the time elapsed (in tenths of seconds), starting when the player clicks the "Play again?" button and stopping when they find the last match.



① Add a line of code to the end of the PlayAgainButton_Clicked event handler to start a timer.

Go to the very end of the PlayAgainButton_Clicked event handler. There are two closing curly brackets } at the end of the method on separate lines. Add three lines between the brackets, then add the following line of code into that space that you created:

```
foreach (var button in AnimalButtons.Children.OfType<Button>())
{
    int index = Random.Shared.Next(animalEmoji.Count);
    string nextEmoji = animalEmoji[index];
    button.Text = nextEmoji;
    animalEmoji.RemoveAt(index);
}

Dispatcher.StartTimer(TimeSpan.FromSeconds(.1), TimerTick);
}
```

The line of code that you just added causes your app to **start a timer** that executes a method called TimerTick every 0.1 of a second.

② Examine the error and click on "TimerTick" in the code you just added.

You just added a line of code to start a timer that "ticks" every 10th of a second. Every time it ticks, it calls a method called TimerTick. But hold on—your C# code doesn't have a TimerTick method. If you try to build your code, you'll see an error in the Error List window:

✘ CS0103 The name 'TimerTick' does not exist in the current context

And there will be a red squiggly line underneath **TimerTick** in the line of code that you added. Click on **TimerTick** in the C# code—when you click on it, Visual Studio will display an icon shaped like a light bulb or screwdriver in the left margin.

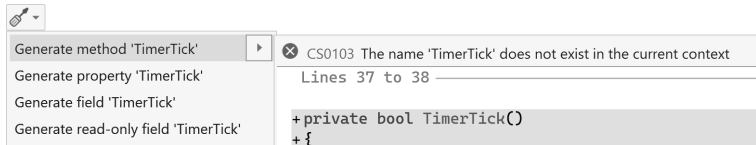
```
35
36         button.Text = nextEmoji;
37         animalEmoji.RemoveAt(index);
38     }
39     Dispatcher.StartTimer(TimeSpan.FromSeconds(.1), TimerTick);
40 }
41
```

When you click on TimerTick in the C# code, Visual Studio displays either a light bulb or screwdriver icon. It looks slightly different in Visual Studio Code, but works the same way.

The red squiggly line tells you under TimerTick that there's an error here.

3 Use Visual Studio to generate a new TimerTick method.

The code that you added has an error because it refers to a method called `TimerTick` that doesn't exist. When you click on it, a light bulb or screwdriver icon shows up in the lefthand margin. If you hover over it, you can see an error message and icon directly underneath it as well:



In VSCode, the Quick Actions icon looks like a light bulb, not a screwdriver.

Clicking the icon brings up the **Quick Actions menu**, which gives you some suggested potential fixes for the error. You can also click on `TimerTick` and press `Alt+Enter` or `Ctrl+.` on Windows or `⌘+.` on a Mac—that's a Control or `⌘` plus period—to on a Mac to bring up the menu:



The first option in the Quick Actions menu should be “Generate method 'TimerTick'”—and if you select that option, you'll see a preview to the right. **Choose that option.**

Visual Studio will **generate the `TimerTick` method for you**. Look through your C# code in `MainPage.xaml.cs` and find the `TimerTick` method that Visual Studio added:

```
private bool TimerTick()
{
    throw new NotImplementedException();
}
```

When your C# code has errors, Visual Studio sometimes has suggestions for potential fixes that can generate code to fix the error.

your game is almost done

Finish the code for your game

In this last part of your project, you'll add a timer to your game to make it more exciting. It will keep track of the time elapsed (in tenths of seconds), starting when the player clicks the "Play again?" button and stopping when they find the last match.

Do this!

Add a field to hold the time elapsed

Find the first line of the `TimerTick` method that you just generated. Place your mouse cursor at the beginning of the line, then press `Enter` twice to add two spaces above it.

Add this line of code right above the `TimerTick` method you just added:

```
int tenthsOfSecondsElapsed = 0; ← This is a field. You'll learn  
private bool TimerTick()      more about how fields  
                               work in Chapter 3.
```

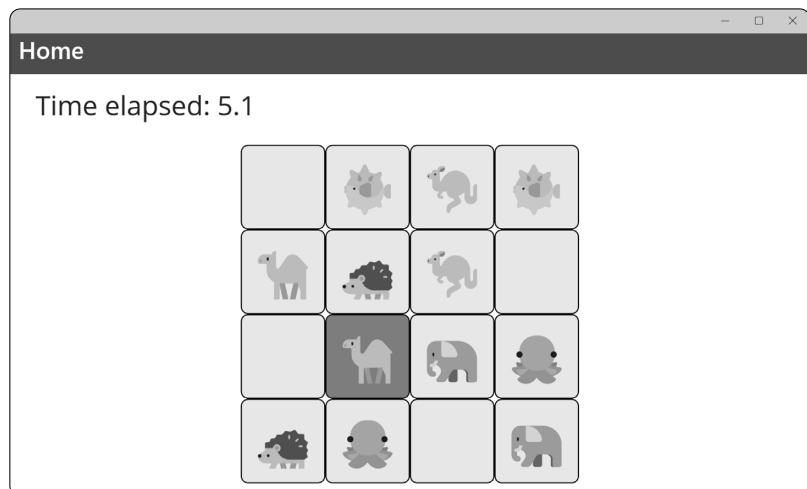
Finish your `TimerTick` method

Now you have everything you need to finish the `TimerTick` method. Here's the code for it:

```
private bool TimerTick()  
{  
    if (!this.IsLoaded) return false;  
  
    tenthsOfSecondsElapsed++;  
  
    TimeElapsed.Text = "Time elapsed: " +  
        (tenthsOfSecondsElapsed / 10F).ToString("0.0s");  
  
    if (PlayAgainButton.IsVisible)  
    {  
        tenthsOfSecondsElapsed = 0;  
        return false;  
    }  
  
    return true;  
}
```

We put an extra line break in this statement so it would fit on the page in the printed book, but you can put it all on one line if you want. Make sure the parentheses match exactly.

Run your game. Now the timer works!





Your Timer Tick Method Up Close

Let's take a closer look at your `TimerTick` method to see how it, well, ticks. It has a total of seven statements, and each of them is important.

```
private bool TimerTick()
{
```

```
    if (!this.IsLoaded) return false;
```

If you close your app, the timer could still tick after the `TimeElapsed` label disappears, which could cause an error. This statement keeps that from happening.

```
    tenthsOfSecondsElapsed++;
```

The timer ticks every 10th of a second. Adding 1 to this field keeps track of how many of those 10ths have elapsed.

This statement updates the `TimeElapsed` label with the latest time, dividing the 10ths of second by 10 to convert it to seconds.

```
    TimeElapsed.Text = "Time elapsed: " +
        (tenthsOfSecondsElapsed / 10F).ToString("0.0s");
```

If the "Play Again?" button is visible again, that means the game is over and the timer can stop running. The `if` statement runs the next two statements only if the game is running.

```
    if (PlayAgainButton.IsVisible)
```

```
    {
```

```
        tenthsOfSecondsElapsed = 0;
```

We need to reset the 10ths of seconds counter so it starts at 0 the next time the game starts.

```
        return false;
```

This statement causes the timer to stop, and no other statements in the method get executed.

```
    }
```

```
    return true;
```

This statement is only executed if the `if` statement didn't find the "Play again?" button visible. It tells the timer to keep running.

```
}
```

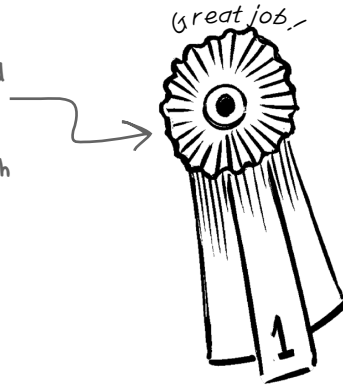
One last thing about the timer. The timer you used is guaranteed to fire no more than once every 10th of a second, but it may fire a little less frequently than that—which means the timer in the game may actually *run a little slow*. For this game, that's absolutely fine!

Even better ifs...

Your game is pretty good. Nice work! Every game—in fact, pretty much every program—can be improved. Here are a few things that we thought of that could make the game better:

- ★ Add different kinds of animals so the same ones don't show up each time.
- ★ Keep track of the player's best time so they can try to beat it.
- ★ Make the timer count down instead of counting up so the player has a limited amount of time.

Congratulations—you built a game, but you did more than that! You took the time to really understand how it works, and that's a very important step in getting comfortable with C# concepts.



Bullet Points

- An **event handler** is a method that your application calls when a specific event like a mouse click happens.
- Visual Studio makes it easy to **add and manage** your event handler methods.
- The IDE's **Error List window** shows any errors that prevent your code from building.
- A **timer** calls a method over and over again on a specified interval.
- **foreach** is a kind of loop that iterates through a collection of items.
- When you have a bug in your code, the first thing to do is try to **figure out what's causing it**.
- Bugs are normal, and sleuthing out bugs is an **important developer skill** that you'll work on throughout this book.
- Visual Studio makes it really easy to use **source control** to back up your code and keep track of all changes that you've made.
- You can commit your code to a remote **Git repository**. We use GitHub for the repository with the source code for all of the projects in this book.



Can you think of your own “even better if” improvements for the game? This is a great exercise—take a few minutes and write down at least three improvements to the animal matching game.

↑
We're serious—take a few minutes and do this. Stepping back and thinking about the project you just finished is a great way to seal the lessons you learned into your brain.

Did you add your code to a Git repo?

If you did, this is a great time to commit all of your changes and push it to the repository!

And if you still haven't, take a few minutes and check out our free **Head First C# Guide to Git** PDF. It gives you step-by-step instructions for keeping your code safe in Git.

Download it today from our own GitHub page: <https://github.com/head-first-csharp/fjfh-edition>

2 variables, statements, and methods

Dive into C# code



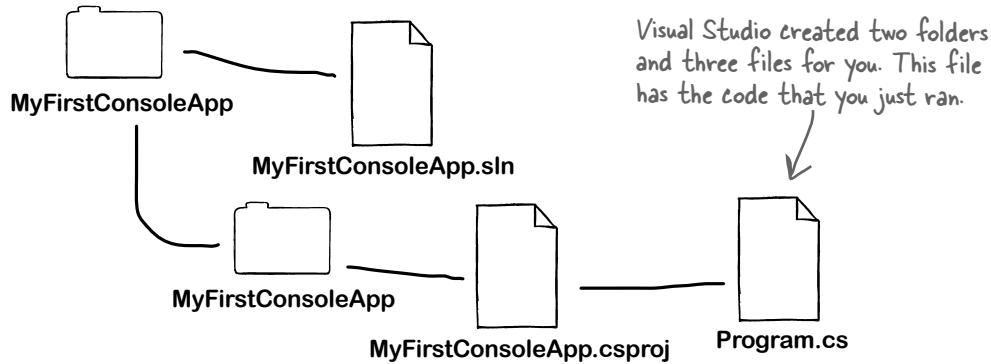
You're not just an IDE user. You're a developer.

You can get a lot of work done using the IDE, but there's only so far it can take you.

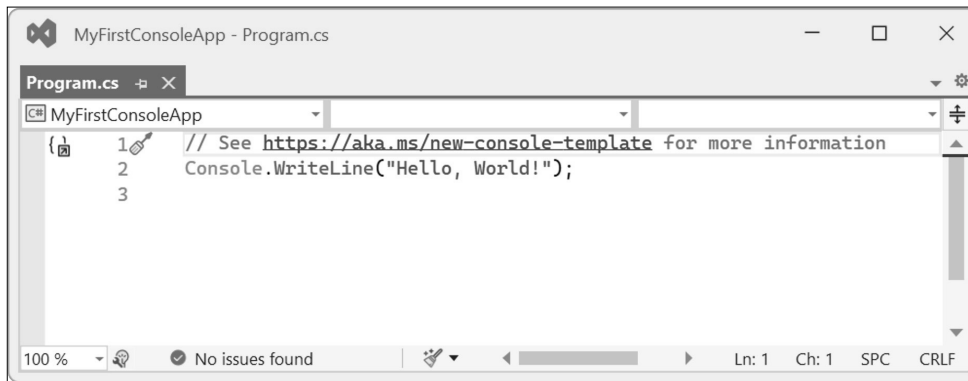
Visual Studio is one of the most advanced software development tools ever made, but a **powerful IDE** is only the beginning. It's time to **dive in to C# code**: how it's structured, how it works, and how you can take control of it...because there's no limit to what you can get your apps to do.

Take a closer look at the files in your console app

In Chapter 1, you created a new C# Console App project and named it `MyFirstConsoleApp`. When you did that, Visual Studio created two folders and three files.



Let's take a closer look at the `Program.cs` file that it created. Open it up in Visual Studio:



This is a screenshot of Visual Studio for Windows. If you're using VSCode the screen will look a little different, but the code will be the same.

A statement performs one single action

A **console app** is an app with a text-only user interface. All its input and output goes to a console, like the Windows command prompt, the macOS Terminal, or Linux Terminal.

Your app has two lines:

1. The first line is a **comment**. Comments start with two forward slashes `//` and everything after those slashes is ignored. You can use comments to write notes about the code.
2. The second line is a **statement**. Statements are what make your code do things. In this case, it's a `Console.WriteLine` statement, which writes a line of text.

When you run your app, it starts with the first statement, and keeps executing statements until it runs out, and since it's a console app you'll see its output in a console window. Once it executes the last statements, the app exits.



So the IDE can really help me out. It **generates code**, and it also helps me **find problems** in my code.

The IDE helps you build your code right.

A long, long, LONG time ago, programmers had to use simple text editors like Windows Notepad or macOS TextEdit to edit their code. In fact, some of their features would have been cutting-edge (like search and replace, or Notepad's Ctrl+G for “go to line number”). We had to use a lot of complex command-line applications to build, run, debug, and deploy our code.

Over the years, Microsoft (and, let's be fair, a lot of other companies, and a lot of individual developers!) figured out how to add *many* helpful things like error highlighting, IntelliSense, WYSIWYG click-and-drag window UI editing, automatic code generation, and many other features.

After years of evolution, Visual Studio is now one of the most advanced code-editing tools ever built. And luckily for us, it's also a **great tool for learning and exploring C# and app development**.

there are no Dumb Questions

Q: I understand what *Program.cs* does—that's where the code for my program lives. But does my program need the other two files and folders?

A: When you created a new project in Visual Studio, it created a **solution** for you. A solution is just a container for your project. The solution file ends in *.sln* and contains a list of the projects that are in the solution, with a small amount of additional information (like the version of Visual Studio used to create it). The **project** lives in a folder inside the solution folder. It gets a separate folder because some solutions can contain multiple projects—but yours only contains one, and it happens to have the same name as the solution (*MyFirstConsoleApp*). The project folder for your app contains two files: a file called *Program.cs* that contains the code, and a **project file** called *MyFirstConsoleApp.csproj* that has all of the information Visual Studio needs to **build** the code, which means turning it into something your computer can run. You'll eventually see **two more folders** underneath your project folder: the **bin folder** will have the executable files built from your C# code, and the **obj folder** will have the temporary files used to build it.

Statements are the building blocks for your apps

Your app is made up of classes, and those classes contain methods, and those methods contain statements. A **statement** is a line of code that does something.

So if we want to build apps that do a lot of things, we'll need a few **different kinds of statements** to make them work. You've already seen one kind of statement:

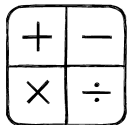
```
Console.WriteLine("Hello, World!");
```

This is a **statement that calls a method**—specifically, the `Console.WriteLine` method, which prints a line of text to the console. We'll also use a few other kinds of statements in this chapter and throughout the book. For example:

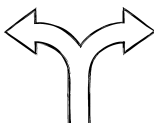
A statement can actually span multiple lines, which you'll see later in this book. But for now, you can just think of "statement" and "line of code" as the same thing.



We use variables and variable declarations to let our app store and work with data.



Lots of programs use math, so we use mathematical operators to add, subtract, multiply, divide, and more.



Conditionals let our code choose between options, either executing one block of code or another.



Loops let our code run the same block over and over again until a condition is satisfied.

Statements live inside methods

You wrote a **method** in Chapter 1 to set up your animal matching game. But what, exactly, is a method?

Methods do something

The `Console.WriteLine` method is part of .NET. It's not hard to guess that a method that starts with "Console." has something to do with reading or writing text in a console app. In this case, it writes a line of text to the console. It's a really useful method, and you'll use it—and a lot of other .NET methods (it has *thousands* of them!)—throughout this book.

You're going to write your own methods, and you're going to write code that **calls** those methods. To call a method, you write a statement that consists of the name of that method followed by parentheses and a semicolon. You can **pass** information to that method by putting it inside those parentheses—like passing "Hello, World!" when your code called the `Console.WriteLine` method.

Methods help you organize your code

Every method is made up of statements, and one method can contain many statements. Code tends to naturally organize into **blocks**, or lines of code which, taken together, do a specific thing. Methods are your way to take those code blocks, give them names, and make them easy to call.

When your program calls a method, it executes the first statement in that method, then the next, then the next, etc. When the method runs out of statements—or hits a **return** statement—it ends, and the program execution resumes after the statement that originally called the method.

Do you really *need* a method? You *could* copy the code in a method and paste it over the statement that called that method, and the app would still work. When you put a block of code into a method and **give it a name**, you make it a lot easier to understand what that code does.



Brain Power

You'll use methods over and over again throughout this book to organize your code. Why do you think your code needs organizing?

When you're writing your code, you can take a block of code and turn it into a single method, multiple methods, or not use methods at all. How do you decide where to break up your code into methods?

The `Console.WriteLine` method writes a line to the console. Does that name make sense to you? Can you think of why it's useful for methods to have sensible names?

Your methods use variables to work with data

Every program, no matter how big or how small, works with data. Sometimes the data is in the form of a document, or an image in a video game, or a social media update—but it's all just data. That's where **variables** come in. A variable is what your program uses to store data.



Declare your variables

Whenever you **declare** a variable, you tell your program its *type* and its *name*. Once C# knows your variable's type, it will generate errors that stop your program from building if you try to do something that doesn't make sense, like subtract "Fido" from 48353. Here's how to declare variables:

```
// Let's declare some variables
int maxWeight;
string message;
bool boxChecked;
```

These are variable types. C# uses the *type* to define what data these variables can hold.

These are variable *names*. C# doesn't care what you name your variables—these names are for you.

This is why it's really helpful for you to choose variable names that make sense and are obvious.

Any line that starts with // is a *comment* and does not get executed. You can use comments to add notes to your code to help people read and understand it.

Whenever your program needs to work with numbers, text, true/false values, or any other kind of data, you'll use variables to keep track of them. The variable's type defines what kind of data it can hold.

Variables vary

A variable is equal to different values at different times while your program runs. In other words, a variable's value *varies*. (Which is why "variable" is such a good name.) This is really important because that idea is at the core of every program you'll write. Say your program sets the variable **myHeight** equal to 63:

```
int myHeight = 63;
```

Any time **myHeight** appears in the code, C# will replace it with its value, 63. Then, later on, if you change its value to 12:

```
myHeight = 12;
```

C# will replace **myHeight** with 12 from that point onward (until it gets set again)—but the variable is still called **myHeight**.

You need to assign values to variables before you use them

Try typing these statements just below the “Hello, World” statement in your new console app:

```
string z;
string message = "The answer is " + z;
```

Go ahead, try it right now. You’ll get an error, and the IDE will refuse to build your code. That’s because it checks each variable to make sure that you’ve assigned it a value before you use it. The easiest way to make sure you don’t forget to assign values to your variables is to combine the statement that declares a variable with a statement that assigns its value:

```
int maxWeight = 25000;
string message = "Hi!";
bool boxChecked = true;
```

These values are assigned to the variables. You can declare a variable and assign its initial value in a single statement (but you don’t have to).

A few useful types

Every variable has a type that tells C# what kind of data it can hold. We’ll go into a lot of detail about the many different C# types in Chapter 4. In the meantime, we’ll concentrate on the three most popular types. **int** holds integers (or numbers without fractions or decimals), **string** holds text, and **bool** holds **Boolean** true/false values.

var-i-a-ble, noun.

an element or feature likely to change.
*Predicting the weather would be a whole lot easier if meteorologists didn’t have to take so many **variables** into account.*

Do this!

If you write code that uses a variable that hasn’t been assigned a value, your code won’t build. It’s easy to avoid that error by combining your variable declaration and assignment into a single statement.

Once you’ve assigned a value to your variable, that value can change. So there’s no disadvantage to assigning a variable an initial value when you declare it.

Generate a new method to work with variables

In Chapter 1, you learned that Visual Studio will **generate code for you**. This is quite useful when you're writing code—and *it's also a really valuable learning tool*. Let's build on what you learned and take a closer look at generating methods.

↙ **Do this!**

1 Add a method to your new MyFirstConsoleApp project.

Open the Console App project that you created in the previous chapter. In **Visual Studio** choose File >> Open >> Project/Solution. In **VSCoDe**, choose File >> Close Folder, then File >> Open Folder.

The *Program.cs* file has two lines of code that we saw in Chapter 1. **Replace those two lines** with this statement—it **calls a method named OperatorExamples**:

`OperatorExamples();` ← A statement with the name of a method followed by opening and closing parentheses () calls that method.

2 Let Visual Studio tell you what's wrong.

As soon as you finish replacing the statements, Visual Studio will draw a red squiggly underline beneath your method call. Hover your mouse cursor over it. The IDE will display a pop-up window:

`OperatorExamples();`



CS0103: The name 'OperatorExamples' does not exist in the current context

Show potential fixes (Alt+Enter or Ctrl+.)

In VSCoDe, the box may look a little different, and instead of "potential fixes" it may say Quick Fix instead.

Visual Studio is telling you two things: that there's a problem—you're trying to call a method that doesn't exist (which will prevent your code from building)—and that it has a **potential fix**.

3 Generate the OperatorExamples method.

In **Visual Studio**, the pop-up window tells you to press Alt+Enter or Ctrl+. to see the potential fixes.

In **VSCoDe**, you may see a "Quick fix" link—press Ctrl+. / ⌘+. to see the potential fixes. Click on OperatorExamples and click the icon that looks like a screwdriver or light bulb (or press Ctrl+. or ⌘+.).

`OperatorExamples();`



The screenshot shows a context menu with the following options:

- Generate method 'OperatorExamples'
- Introduce local for 'OperatorExamples()'
- ★ IntelliCode suggestion based on recent edits: OperatorExamples() ▶

The preview window shows the following code:

```
void OperatorExamples()  
{  
    throw new NotImplementedException();  
}
```

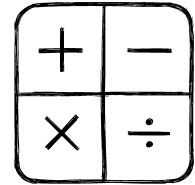
When the IDE generates a new method for you, it adds this "throw" statement as a placeholder—if you run your program, it will halt as soon as it hits that statement. You'll replace that "throw" statement with code.

This screenshot is from Windows. VSCoDe may not show you a preview of the generated code.

Choose the option to generate the method. The IDE will add three lines of code to *Program.cs* that match the code in the preview window. Your top-level statements now have an OperatorExample method.

Add code that uses operators to your method

Once you've got some data stored in a variable, what can you do with it? Well, if it's a number, you might want to add or multiply it. If it's a string, you might join it together with other strings. That's where operators come in. Here's the **method body** for your new OperatorExamples method. **Add this code to your program**, and read the comments to learn about the operators it uses.



```
void OperatorExamples()
{
    // This statement declares a variable and sets it to 3
    int width = 3;

    // The ++ operator increments a variable (adds 1 to it)
    width++;

    // Declare two more int variables to hold numbers and
    // use the + and * operators to add and multiply values
    int height = 2 + 4;
    int area = width * height;
    Console.WriteLine(area);

    // The next two statements declare string variables
    // and use + to concatenate them (join them together)
    string result = "The area";
    result = result + " is " + area;
    Console.WriteLine(result);

    // A Boolean variable is either true or false
    bool truthValue = true;
    Console.WriteLine(truthValue);
}
```

When you generated the OperatorExamples method, the IDE generated code that included the statement `throw new NotImplementedException();` You should *delete* that statement and *replace* it with the code we've given you, so your OperatorExample method *matches our code exactly*. Be very careful that all of the quotes, parentheses, math symbols, and semicolons *match*—it's easy to make a typo.

String variables hold text. When you use the + operator with strings, it joins them together. Adding "abc" + "def" results in a single string, "abcdef."

Sharpen your pencil

The statements you just added to your code will write three lines to the console: each `Console.WriteLine` statement prints a separate line. **Before you run your code**, figure out what they'll be and write them down. And don't bother looking for a solution, because we didn't include one! Just run the code to check your answers.

Here's a hint: converting a bool to a string results in either False or True.

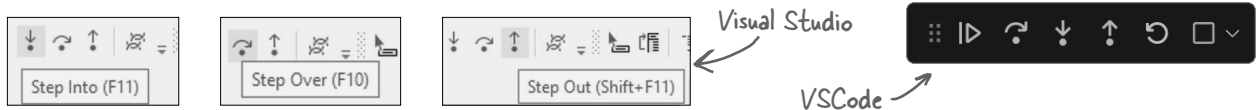
Line 1: _____

Line 2: _____

Line 3: _____

Use the debugger to watch your variables change

When you ran your program earlier, it was executing in the **debugger**—and that’s an incredibly useful tool for understanding how your programs work. You can use **breakpoints** to pause your program when it hits certain statements and add **watches** to look at the value of your variables. Let’s use the debugger to see your code in action. We’ll use these three features of the debugger, which you’ll find in the toolbar:

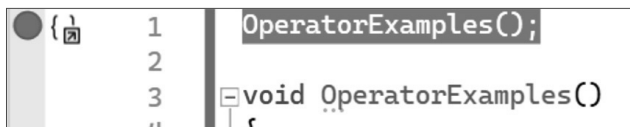


If you end up in a state you don’t expect, just use the Restart button (🔄) to restart the debugger.

Debug this!

1 Add a breakpoint and run your program.

Click on the first line of your program and **press F9 to add a breakpoint**. The line should now look like this—the line should be highlighted in red with a dot in the left margin:



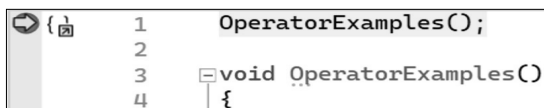
The screens in VSCode will look slightly different, but the debugger works the same way, with the same shortcut keys.

Then press the `▶ MyFirstConsoleApp` button to run your program in the debugger, just like you did earlier.

If your app doesn’t pause on the breakpoint, make sure you’re starting the app with debugging. Run the app by pressing F5 or choosing Start Debugging from the Debug (Visual Studio) or Run (VSCode) menu.

2 Step into the method.

Your debugger is stopped at the breakpoint on the statement that calls the `OperatorExamples` method.

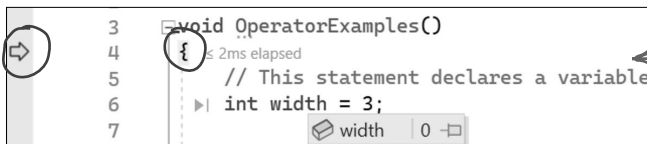


The red background and dot show you where you’ve set breakpoints. The yellow arrow and highlight show the line of code the debugger is paused on.

Press Step Into (F11)—the debugger will jump into the method and pause before it runs the first statement.

3 Examine the value of the width variable.

When you’re **stepping through your code**, the debugger pauses after each statement that it executes. This gives you the opportunity to examine the values of your variables. Hover over the **width** variable.

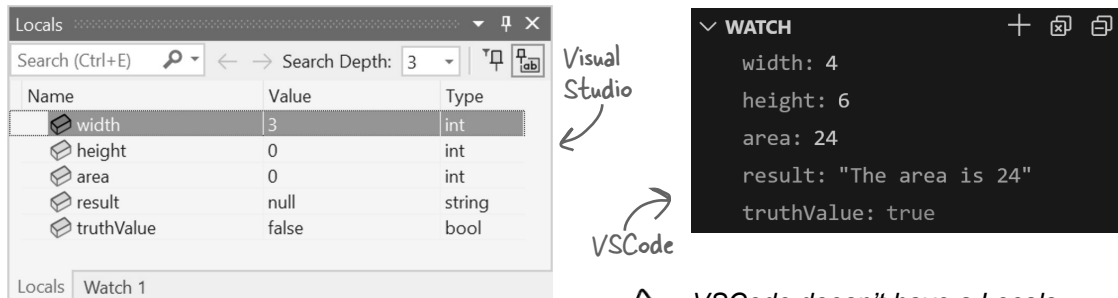


The highlighted bracket and arrow in the left margin mean the code is paused just before the first statement of the method.

The IDE displays a pop-up that shows the current value of the variable—it’s currently 0. Now **press Step Over (F10)**—it goes past the comment to the first statement, which is now highlighted. Now **press Step Over again**, then hover over **width** again. It now has a value of 3.

4 The Locals window shows the values of your variables.

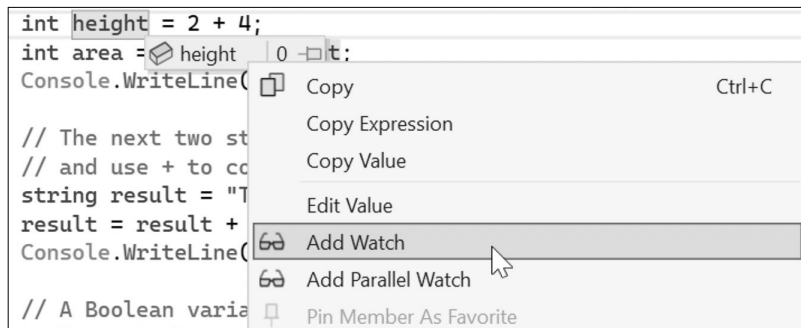
The variables that you declared are **local** to your `OperatorExamples` method—which just means that they exist only inside that method, and can only be used by statements in the method. Visual Studio displays their values in the Locals window at the bottom of the IDE when it's debugging.



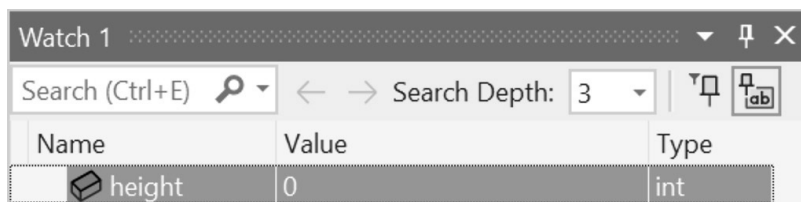
⚠️ *VSCode doesn't have a Locals window yet, but the Watch window works just like the one in Visual Studio.*

5 Add a watch for the height variable.

A really useful feature of the debugger is the **Watch window**, which is typically in the same panel as the Locals window at the bottom of the IDE. When you hover over a variable, you can add a watch by right-clicking on the variable name in the pop-up window and choosing **Add Watch**. Hover over the `height` variable, then right-click and choose **Add Watch** from the menu.



Now you can see the `height` variable in the Watch window.



6 Step through the rest of the method.

Step over each statement in `OperatorExamples`. As you step through the method, keep an eye on the Locals or Watch window and watch the values as they change. On **Windows**, press **Alt+Tab** before and after the `Console.WriteLine` statements to switch back and forth to the Debug Console to see the output. On **macOS**, you'll see the output in the Terminal window so you don't need to switch windows.

The debugger is one of the most important features in Visual Studio, and it's a great tool for understanding how your programs work.

use double equals to check if things are the same


Use code snippets to help write loops



At the time we're writing this, VSCode does not support C# code snippets.

You'll be writing a lot of loops throughout this book, and Visual Studio can help speed things up for you with **snippets**, or simple templates that you can use to add code. Let's use snippets to add a few loops to your `OperatorExamples` method.

Do this!

If your code is still running, choose **Stop Debugging (Shift+F5)** from the Debug menu (or press the Stop button  in the toolbar). Then find the line `Console.WriteLine(area);` in your `OperatorExamples` method. Click at the end of that line so your cursor is after the semicolon, then press Enter a few times for some space. Now start your snippet. Press Ctrl+K, Ctrl+X (so hold down control and press K and then X) to bring up the Insert Snippet box. Choose "Visual C#" and then **type or click while and press Enter**. The IDE will add a template for a **while** loop to your code, with the conditional test highlighted:

```
while (true)
{
  ...
}
```

Type `area < 50`—the IDE will replace `true` with the text. Press Enter to finish the snippet. Then add two statements between the brackets:

```
while (area < 50)
{
  height++;
  area = width * height;
}
```

You can also type in this code instead of using a snippet. Visual Studio Code may not support snippets.



IDE Tip: Brackets

If your brackets (or braces, either name will do) don't match up, your program won't build, which leads to frustrating bugs. Luckily, the IDE can help with this! Put your cursor on a bracket, and the IDE highlights its match.

Next, use the **do/while loop snippet** to add another loop immediately after the while loop you just added. Press Ctrl+K, Ctrl+X and choose the C# snippet. The IDE will add this snippet:

```
do
{
  ...
} while (true);
```

Again, you can just type in the code instead of using a snippet.

For most snippets you can type the snippet name and press tab twice. Go to a blank line and try it—type the word "do" and press the tab key twice.

Type `area > 25` and press Enter to finish the snippet. Then add two statements between the brackets:

```
do
{
  width--;
  area = width * height;
} while (area > 25);
```

Now **use the debugger** to really get a good sense of how these loops work:

1. Click on the line of code just above the first loop and choose **Toggle Breakpoint (F9)** from the Debug menu to add a breakpoint. Then run your code and **press F5** to skip to the new breakpoint.
2. Use **Step Over (F10)** to step through the two loops. Watch the Locals window as the values for `height`, `width`, and `area` change.
3. Stop the program, then change the `while` loop test to `area < 20` so both loops have conditions that are false. Debug the program again. The `while` checks the condition first and skips the loop, but the `do/while` executes it once and then checks the condition.

Use operators to work with variables

Once you have data in a variable, what do you do with it? Well, most of the time you'll want your code to do something based on the value. That's where **equality operators**, **relational operators**, and **logical operators** become important.

Equality Operators

The `==` operator compares two things and is true if they're equal.

The `!=` operator works a lot like `==`, except it's true if the two things you're comparing are not equal.

Relational Operators

Use `>` and `<` to compare numbers and see if a number in one variable is bigger or smaller than another.

You can also use `>=` to check if one value is greater than or equal to another, and `<=` to check if it's less than or equal.

Logical Operators

You can combine individual conditional tests into one long test using the `&&` operator for **and** and the `||` operator for **or**.

Here's how you'd check if `i` equals 3 **or** `j` is less than 5:
`(i == 3) || (j < 5)`



Watch it! Don't confuse the two equals sign operators!

You use one equals sign (=) to set a variable's value, but two equals signs (==) to compare two variables. You won't believe how many bugs in programs—even ones made by experienced programmers!—are caused by using = instead of ==. If you see the IDE complain that you "cannot implicitly convert type 'int' to 'bool,'" that's probably what happened.

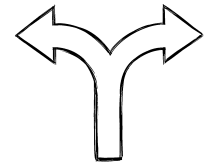
Use operators to compare two int variables

You can do simple tests by checking the value of a variable using a comparison operator. Here's how you compare two ints, `x` and `y`:

```
x < y (less than)
x > y (greater than)
x == y (equals - and yes, with two equals signs)
```

These are the ones you'll use most often.

if statements make decisions



Use **if statements** to tell your program to do certain things only when the **conditions** you set up are (or aren't) true. The **if** statement *tests the condition* and executes code if the test passes. A lot of **if** statements check if two things are equal. That's when you use the **==** operator. That's different from the single equals sign (**=**) operator, which you use to set a value.

```
int someValue = 10;  
string message = "";
```

```
if (someValue == 24)  
{  
    message = "Yes, it's 24!";  
}
```

Every if statement starts with a test in parentheses, followed by a *block* of statements in brackets to execute if the test passes.

The statements inside the curly brackets are executed only if the test is true.

if/else statements also do something if a condition isn't true

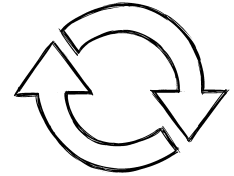
if/else statements are just what they sound like: if a condition is true they do one thing *or else* they do the other. An **if/else** statement is an **if** statement followed by the **else** keyword followed by a second set of statements to execute. If the test is true, the program executes the statements between the first set of brackets. Otherwise, it executes the statements between the second set.

```
if (someValue == 24)  
{  
    // You can have as many statements  
    // as you want inside the brackets  
    message = "The value was 24."  
}  
else  
{  
    message = "The value wasn't 24."  
}
```

REMEMBER—always use two equals signs to check if two things are equal to each other.

Loops perform an action over and over

Here's a peculiar thing about most programs (*especially* games!): they almost always involve doing certain things over and over again. That's what **loops** are for—they tell your program to keep executing a certain set of statements as long as some condition is true or false.



while loops keep looping statements while a condition is true

In a **while loop**, all of the statements inside the curly brackets get executed as long as the condition in the parentheses is true:

```
while (x > 5)
{
    // Statements between these brackets will
    // only run if x is greater than 5, then
    // will keep looping as long as x > 5
}
```

do/while loops run the statements then check the condition

A **do/while** loop is just like a **while** loop, with one difference. The **while** loop does its test first, then runs its statements only if that test is true. The **do/while** loop runs the statements first, *then* runs the test. So if you need to make sure your loop always runs at least once, a **do/while** loop is a good choice:

```
do
{
    // Statements between these brackets will run
    // once, then keep looping as long as x > 5
} while (x > 5);
```

for loops run a statement after each loop

A **for loop** runs a statement after each time it executes a loop.

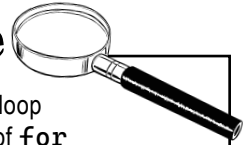
Every for loop has *three statements*. The first statement sets up the loop. It will keep looping as long as the second statement is true. The third statement gets executed after each time through the loop.

```
for (int i = 0; i < 8; i = i + 2)
{
    // Everything between these brackets
    // is executed four times
}
```

The parts of the for statement are called the *initializer* (`int i = 0`), the *conditional test* (`i < 8`), and the *iterator* (`i = i + 2`). Each time through a for loop (or any loop) is called an *iteration*.

The conditional test always runs at the beginning of each iteration, and the iterator always runs at the end of the iteration.

for Loops Up Close



A **for loop** is a little more complex than a **while** loop or **do** loop. The most common type of **for** loop just counts up to a length. The **for code snippet** causes the IDE to create an example of that kind of **for** loop:

```
for (int i = 0; i < length; i++)
{
    ...
}
```

← When you use the “for” snippet, press Tab to switch between *i* and *length*. If you change the name of the variable *i*, the snippet will automatically change the other two occurrences of it.

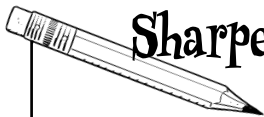
A **for loop** has four sections—an initializer, a condition, an iterator, and a body:

```
for (initializer; condition; iterator) {
    body
}
```

Most of the time you’ll use the initializer to declare a new variable—for example, the initializer `int i = 0` in the previous **for** code snippet declares a variable called *i* that can only be used inside the **for** loop. The loop will then execute the body—which can either be one statement or a block of statements inside curly braces—as long as the condition is true. At the end of each iteration, the **for** loop executes the iterator. So this loop:

```
for (int i = 0; i < 10; i++) {
    Console.WriteLine(“Iteration #” + i);
}
```

will iterate 10 times, printing **Iteration #0, Iteration #1, ..., Iteration #9** to the console.



Sharpen your pencil

Here are a few loops. Write down if each loop will repeat forever or eventually end. If it’s going to end, how many times will it loop? Also, answer the questions in the comments in loops #2 and #3.

```
// Loop #1
int count = 5;
while (count > 0) {
    count = count * 3;
    count = count * -1;
}
```

Remember, a for loop always runs the conditional test at the beginning of the block, and the iterator at the end of the block.

```
// Loop #4
int i = 0;
int count = 2;
while (i == 0) {
    count = count * 3;
    count = count * -1;
}
```

```
// Loop #2
int j = 2;
for (int i = 1; i < 100; i = i * 2)
{
    j = j - 1;
    while (j < 25)
    {
        // How many times will
        // the next statement
        // be executed?
        j = j + 5;
    }
}
```

```
// Loop #5
while (true) { int i = 1;}
```

```
// Loop #3
int p = 2;
for (int q = 2; q < 32; q = q * 2)
{
    while (p < q)
    {
        // How many times will
        // the next statement
        // be executed?
        p = p * 2;
    }
    q = p - q;
}
```

↑
Hint: *p* starts out equal to 2. Think about when the statement “*p* = *p* * 2” is executed.

Some useful things to keep in mind about C# code

- ★ **Don't forget that all your statements need to end in a semicolon.**

```
name = "Joe";
```

- ★ **Add comments to your code by starting a line with two slashes.**

```
// This text is ignored
```

- ★ **Use `/*` and `*/` to start and end comments that can include line breaks.**

```
/* This comment
   * spans multiple lines */
```

- ★ **Variables are declared with a type followed by a *name*.**

```
int weight;
// The variable's type is int and its name is weight
```

- ★ **Most of the time, extra whitespace is fine.**

```
So this:      int      j      =      1234      ;
is exactly the same as this: int j = 1234;
```

- ★ **If/else, while, do, and for are all about testing conditions.**

Every loop we've seen so far keeps running as long as a condition is true.



There's a flaw in your logic! What happens if I write a loop with a conditional test that never becomes false?

Then your loop runs forever.

Every time your program runs a conditional test, the result is either **true** or **false**. If it's **true**, then your program goes through the loop one more time. Every loop should have code that, if it's run enough times, should cause the conditional test to eventually return **false**. If it doesn't, then the loop will keep running until you kill the program or turn the computer off!

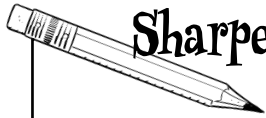
This is sometimes called an infinite loop, and there are definitely times when you'll want to use one in your code.



Brain Power

Can you think of a reason that you'd want to write a loop that never stops running?

When we give you pencil-and-paper exercises, we'll usually give you the solution on the next page.



Sharpen your pencil Solution

Here are a few loops. Write down if each loop will repeat forever or eventually end. If it's going to end, how many times will it loop? Also, answer the questions in the comments in loops #2 and #3.

```
// Loop #1
int count = 5;
while (count > 0) {
  count = count * 3;
  count = count * -1;
}
```

Loop #1 executes once.

Remember, `count = count * 3` multiplies `count` by 3, then stores the result (15) back in the same `count` variable.

```
// Loop #4
int i = 0;
int count = 2;
while (i == 0) {
  count = count * 3;
  count = count * -1;
}
```

Loop #4 runs forever.

```
// Loop #2
int j = 2;
for (int i = 1; i < 100; i = i * 2) {
  j = j - 1;
  while (j < 25) {
    // How many times will
    // the next statement
    // be executed?
    j = j + 5;
  }
}
```

Loop #2 executes seven times.

The statement `j = j + 5` is executed 6 times.

```
// Loop #5
while (true) { int i = 1;}
```

Loop #5 is also an infinite loop.

```
// Loop #3
int p = 2;
for (int q = 2; q < 32; q = q * 2) {
  while (p < q) {
    // How many times will
    // the next statement
    // be executed?
    p = p * 2;
  }
  q = p - q;
}
```

Loop #3 executes eight times.

The statement `p = p * 2` executes three times.



Remember, if your app doesn't pause on the breakpoint, make sure you're starting the app with debugging. Run the app by pressing `F5` or choosing Start Debugging from the Debug (Visual Studio) or Run (VSCode) menu.

Take the time to really figure out how loop #3 works. Here's a perfect opportunity to try out the debugger on your own! Set a breakpoint on `q = p - q`; and add watches for `p` and `q` to keep track of how the values of `p` and `q` change as you step through the loop.



Sharpen your pencil

Let's get some practice working with conditionals and loops. Update the code in your Program file to match the following new code, including TryAnIf, TryAnIfElse, and TrySomeLoops methods. **Before you run your code**, read it carefully and try to answer the questions based on how you think it will run. Then run your code and see if you got them right.

```
TryAnIf();
TrySomeLoops();
TryAnIfElse();
```

What does the TryAnIf method write to the console?

```
void TryAnIf()
{
    int someValue = 4;
    string name = "Bobbo Jr.";
    if ((someValue == 3) && (name == "Joe"))
    {
        Console.WriteLine("x is 3 and the name is Joe");
    }
    Console.WriteLine("this line runs no matter what");
}
```

.....

.....

```
void TryAnIfElse()
{
```

```
    int x = 5;
    if (x == 10)
    {
        Console.WriteLine("x must be 10");
    }
    else
    {
        Console.WriteLine("x isn't 10");
    }
}
```

What does the TryAnIfElse method write to the console?

.....

```
void TrySomeLoops()
{
```

```
    int count = 0;

    while (count < 10)
    {
        count = count + 1;
    }

    for (int i = 0; i < 5; i++)
    {
        count = count - 1;
    }
}
```

What does the TrySomeLoops method write to the console?

.....

```
    Console.WriteLine("The answer is " + count);
}
```

We didn't include answers for this exercise in the book. After you write down the answers, create a new console app—just like you did in Chapter 1—and add this code, then check the output to see if your answers are correct.



Game Design...and Beyond

Mechanics

The **mechanics** of a game are the aspects of the game that make up the actual gameplay: its rules, the actions that the player can take, and the way the game behaves in response to them.

- Let's start with a classic video game. The **mechanics of Pac-Man** include how the joystick controls the player on the screen, the number of points for dots and power pellets, how ghosts move, how long they turn blue and how their behavior changes after the player eats a power pellet, when the player gets extra lives, how the ghosts slow down as they go through the tunnel—all of the rules that drive the game.

If you haven't played Pac-Man before, take a few minutes and watch a video of its gameplay. Even better, play it yourself! There are many ways to play it. One easy way is to search Google for "Pac-Man"—they created a playable Pac-Man game for its 30th anniversary that works in your browser using the arrow keys.

- When game designers talk about a **mechanic** (in the singular), they're often referring to a single mode of interaction or control, like a double jump in a platformer or shields that can only take a certain number of hits in a shooter. It's often useful to isolate a single mechanic for testing and improvement.
- **Tabletop games** give us a really good way to understand the concept of mechanics. Random number generators like dice, spinners, and cards are great examples of specific mechanics.
- You've already seen a great example of a mechanic: the **timer** that you added to your animal matching game changed the entire experience. Timers, obstacles, enemies, maps, races, points...these are all mechanics.
- Different mechanics **combine** in different ways, and that can have a big impact on how the players experience the game. Monopoly is a great example of a game that combines two different random number generators—dice and cards—to make a more interesting and subtle game.
- Game mechanics also include the way the **data is structured and the design of the code** that handles that data—even if the mechanic is unintentional! Pac-Man's legendary *level 256 glitch*, where a bug in the code fills half the screen with garbage and makes the game unplayable, is part of the mechanics of the game.
- When we talk about the mechanics of a game written in C#, **that includes the classes and the code**, because they drive the way that the game works.

Here's another one of those "Game Design...and Beyond" sections. This one is all about mechanics, an important part of video game design. If you're not interested in writing video games, read these sections anyway! They have important concepts that we'll build on throughout the book.



*I bet the concept of mechanics can help me with **any** kind of project, not just games.*

Definitely! Every program has its own kind of mechanics.

There are mechanics at every level of software design. They're easier to talk about and understand in the context of video games. We'll take advantage of that to help give you a deeper understanding of mechanics, which is valuable for designing and building any kind of project.

The mechanics of a game determine how hard or easy it is to play. Here's an example: make Pac-Man move faster or slow down the ghosts, and the game gets easier. That doesn't necessarily make it better or worse—just different. And guess what? The same idea applies to how you design your classes! You can think of **how you design your methods and fields** as the mechanics of the class. The choices you make about how to break up your code into methods or when to use fields make them easier or more difficult to use.

Bullet Points

- **Methods** are made up of statements. Calling a method executes its statements in order.
- Putting statements into a method and giving it a name helps make your code **easier to read**.
- When a method runs out of statements or executes a **return** statement, **execution resumes after the statement** that originally called the method.
- A variable's **type** determines what kind of data—like whole or decimal numbers, text, or true/false values—that it can hold
- You need to **assign values** to variables before you can use them.
- **Operators** like +, -, *, and / perform manipulations on the data stored in variables. The = operator assigns a value, while the == operator compares two values.
- **if statements** tell your program to do certain things only when the conditions you set up are (or aren't) true.
- **Loops** execute a set of statements over and over again until a condition is met. **for**, **while**, and **do/while** loops all iterate over statements multiple times, but they work differently from each other.
- Visual Studio's **code snippets** feature helps you write **if** statements and loops.

artificial intelligence can help you learn

The Sens-AI elements are all about helping you use an AI chatbot as a virtual C# sensei. We wanted to start the first one with an example of just how powerful AI chatbots can be, so we asked Copilot to write this introduction. (We also asked it for permission to include its output in the book.)

Exploring C# with AI Chatbots: A Unique Learning Journey

Welcome to the fascinating world of C# development! As an author, you've already embarked on a mission to make learning engaging and memorable. Now, let's take it up a notch by introducing a powerful ally: **AI chatbots**.

Why AI Chatbots?

Imagine having a friendly, tireless companion by your side—one that not only answers your questions but also challenges you to think critically, nudges you in the right direction, and celebrates your victories. That's precisely what AI chatbots can do for aspiring C# developers.

In this section, we'll delve into the pedagogical uses of AI chatbots, exploring how they can enhance the learning experience, spark curiosity, and empower learners to explore C# independently.

The Generative Magic Behind Chatbots

Before we dive in, let's demystify the magic. Designers harness a variety of machine learning and deep learning techniques to create large language models (LLMs) that form the backbone of generative AI chatbots. These bots can generate text, simulate conversations, and adapt to user input—while maintaining an engaging and conversational tone.

Seven Approaches to Educational Chatbot Use

- **AI as Mentor:** Timely feedback is crucial for learning. An AI chatbot can provide students with frequent, immediate, and adaptive feedback. Whether it's essay structure or code debugging, the chatbot acts as a mentor, guiding learners toward mastery.
- **AI as Tutor:** Effective tutoring involves personalized instruction and skill-building. Chatbots can supplement traditional tutoring, offering explanations, analogies, and open-ended questions tailored to individual interests.
- **AI as Collaborator:** Imagine brainstorming with an AI buddy. Chatbots can collaborate on problem-solving, code design, and creative thinking. They're the perfect coding companions for late-night sessions.
- **AI as Debugger:** Debugging code can be frustrating. Chatbots can analyze code snippets, identify errors, and suggest fixes. They're like virtual debugging partners, always ready to lend a hand.
- **AI as Code Generator:** Need inspiration? Chatbots can generate code snippets, templates, and even entire functions. They're the Swiss Army knives of C# development.
- **AI as Quizmaster:** Reinforce learning with quizzes. Chatbots can quiz learners on syntax, concepts, and best practices. Plus, they won't judge you for forgetting semicolons.
- **AI as Curator:** Curate resources, recommend tutorials, and keep learners updated. Chatbots can be your personalized C# library, accessible 24/7.

Your Hands-On Journey Begins

Throughout this section, we'll guide you through hands-on tasks. You'll reflect on educational uses of AI chatbots, access commonly used generative AI tools, and practice interacting with a chatbot. Remember, while AI is powerful, critical examination is essential. Let's explore, learn, and code together!

We agree!

“Sensei” is a Japanese term that encompasses the role of teacher or instructor.



dive into c# code

Sens-AI

First lesson: AI chatbots aren't perfect...and that's OK

When you use an AI chatbot like Copilot, ChatGPT, Gemini, or Claude, you start with a **prompt**, or a question, statement, or other kind of query to initiate a conversation. We used this prompt to generate the introduction to this section:

I'm the author of Head First C#, a book that aims to help people learn about development with C# in a unique and engaging way. A section of that book is about how to use AI chatbots as a tool to learn and explore C# on their own. Can you help me write the introduction to that section?

It came up with a great introduction—it's good enough for us to use in this book! But it isn't perfect. Take a look at the second sentence that starts, “As an author, you've...”—that's not quite right. The chatbot may have gotten a bit confused because we started our prompt with “I'm the author.” This book isn't for authors, it's for people learning to be C# developers. *Your mission isn't making learning engaging and memorable—that's our mission!*

How to use AI safely: Trust but verify

It's pretty amazing that the AI gave us such great text, even if we might want to edit it a little (like replace 'pedagogical' with 'teaching-related').

Using AI chatbots is a skill that's becoming increasingly important to developers. One of our goals is to help you use AI chatbots in a way that's **safe**, which means that you have to *confirm two things yourself*: that everything you learn from an AI is actually and factually **correct**, and that any code the AI generates for you **does what you want it to do**. We'll include these Sens-AI elements throughout this to help you learn how to confirm those things and use AI safely.

Here's an example of the strengths and weaknesses of AI. We gave this prompt to Copilot, ChatGPT, and Gemini:

I have the following for loop in C#:

```
int p = 2;
for (int q = 2; q < 32; q = q * 2)
{
    while (p < q)
    {
        // How many times will the next
        // statement be executed?
        p = p * 2;
    }
    q = p - q;
}
```

We copied this code directly from the “Sharpen your pencil” earlier in this chapter. You can include code directly in your prompts.

When you're typing a prompt into a browser-based AI chatbot, you may need to use *Shift-Enter* to add line breaks. We recommend using a text editor like VSCode, Windows Notepad, or macOS TextEdit to edit your prompts. You can copy and paste them into the browser—and then you can save them in a folder for later.

How does it work, and how many times are the inner and outer loops executed?

The AI chatbots all gave an excellent explanation of how the loop worked—and all three **gave us wrong answers** for how many times the loops are executed. In fact, they all gave different answers. We asked the same question a few days later, and all three chatbots gave *three entirely different wrong answers*. And that's OK! AI technology is always improving. It may never be perfect, but it will always be a **helpful and valuable learning tool**.

AI researchers are constantly updating their models with questions and their correct answers, so it may get the answer right because the question and answer are in its database.

Try it out yourself

Open Copilot (<https://copilot.microsoft.com>), ChatGPT (<https://chat.openai.com>), Gemini (<https://gemini.google.com>), Claude (<https://claude.ai>) or any other AI chatbot, and type in the prompt about loops that we just showed you. Modify the code in the prompt to replace it with other loops in the “Sharpen” exercise. Did the AI explain the loops well? Did it get the counts right?

AI chatbots don't always give correct answers, in part because they use statistical models—not actual thinking!—to generate sentences. But if you understand their limitations and practice using them, they can be really useful.

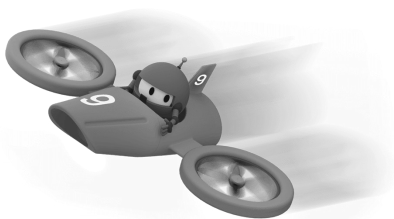
Controls drive the mechanics of your user interfaces

In Chapter 1, you built a game using Button and Label **controls**. There are a lot of different ways that you can use controls, and the choices you make about what controls to use can really change your app. Does that sound weird? It's actually *very similar to the way we make choices about mechanics in game design*. If you're designing a tabletop game that needs a random number generator, you can choose to use dice, a spinner, or cards. If you're designing a platformer, you can choose to have your player jump, double jump, wall jump, or fly (or do different things at different times). The same goes for apps: if you're designing an app where the user needs to enter a number, you can choose from different controls to let them do that... *and that choice affects how your user experiences the app*.

Meet some of the controls you'll use in this book

Most of the chapters in this book feature a .NET MAUI project. We included them so you can go beyond console apps and start learning how to build visual apps. In those projects, you'll use many different controls to build each app's **user interface** (or **UI**)—or the way the window is laid out so the user can interact with it—of each app.

Here are the controls you've seen so far.



An *Image* control does exactly what you'd expect it to do—it displays an image. In this case, it's displaying the image in a file called `dotnet_bot.png`.

Hello, World!

A *label* displays text. You can set the font size, color, spacing, and text decorations (like italics or boldface).

A *Button* control shows a clickable button. It can call a method when you click it, and you can set or change its text.

Click me

We'll spend the rest of this chapter building a MAUI app to experiment with controls. You can find an equivalent web development project in the *Head First C# Blazor Learner's Guide*, which you can download from our GitHub page: <https://github.com/head-first-csharp/fifth-edition>

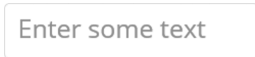
The user interface, or UI, is the part of the app that your user interacts with. In a console app, the UI is made up of text, and the user uses the keyboard to interact with it. In a MAUI app, the UI is built using controls.

Other controls you'll use in this book

Controls are common user interface components, and they serve as the building blocks of your UI. The choices you make about what controls to use change the mechanics of your app.

Most of the chapters in this book contain a .NET MAUI project. You'll use various controls to build the UI for each of those apps. Here are a few of the ones that you'll use.

We can borrow the idea of mechanics from video games to understand our options, so we can make great choices for any of our apps—not just games.



An Entry control lets your user enter text. It displays a placeholder, or lighter-colored text that gives the user some information about what they should type.

This is a multiline Label control.

A Label can include multiple lines, which are separated by line breaks so it knows how to split them up.



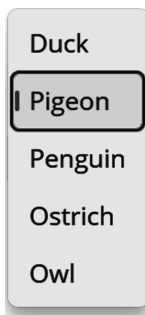
A Switch is a horizontal button that lets the user toggle (or switch back and forth) between two states, in this case on and off.



These are two different controls that let users enter numbers. A Stepper (on the left) presents the user with two buttons to increment or decrement—add or remove one—to a value. A Slider (on the right) lets the user slide back and forth to choose a decimal number.

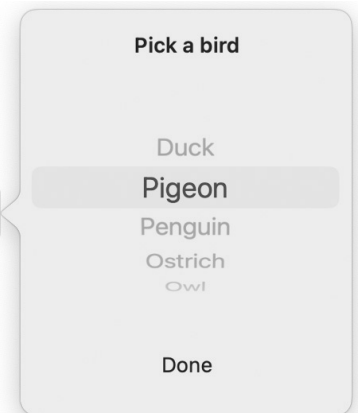


Pick a bird



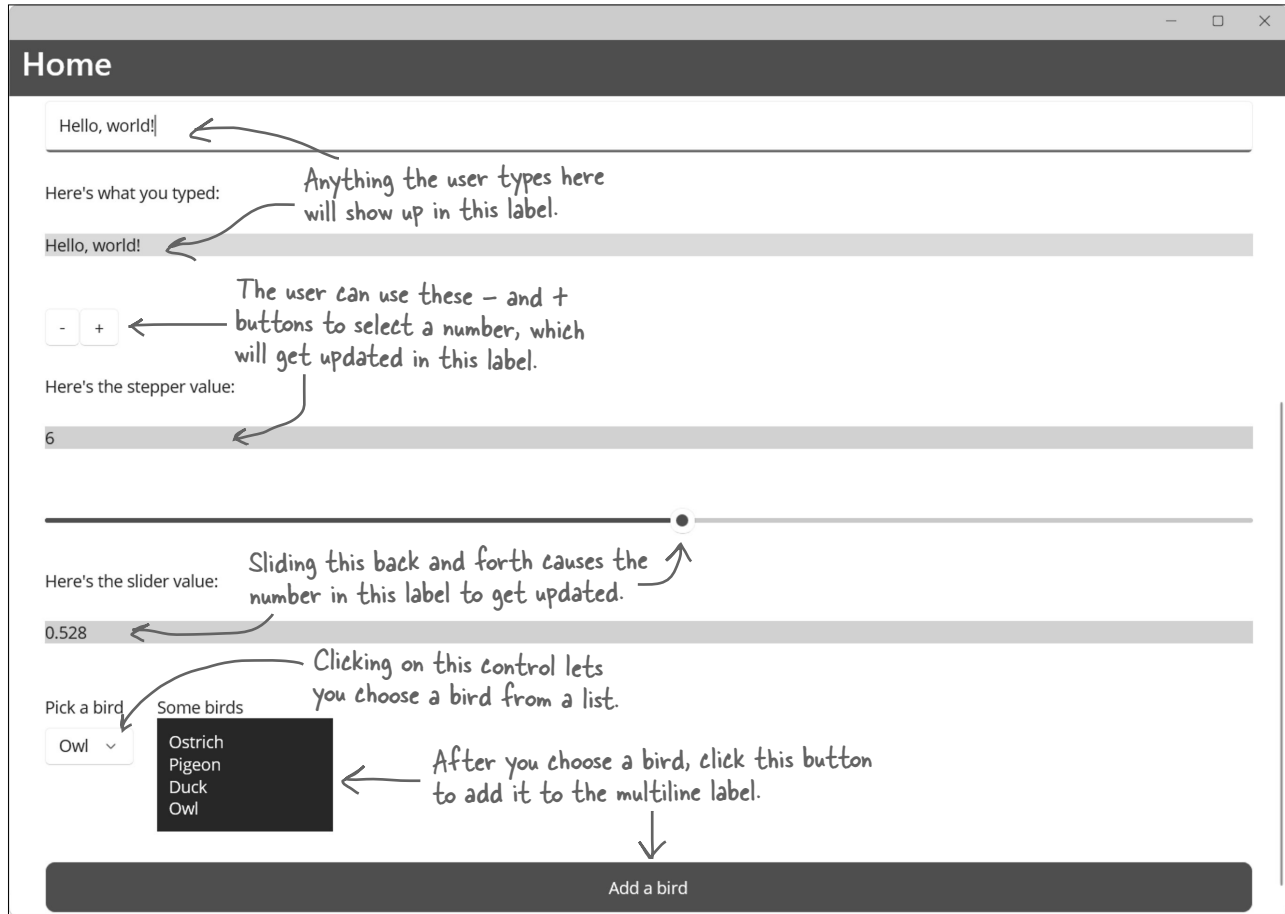
A Picker lets the user choose an item from a list. It looks a little different in Windows (on the left) and macOS (on the right), but both versions function in exactly the same way.

Pigeon



Build a .NET MAUI app to experiment with controls

You've probably seen most of the controls we just showed you (even if you didn't know all of their official names). Now let's **create a .NET MAUI app** to get some practice using some of them. The app will be really simple—the user will use controls to enter values, and the app will display those values.



Relax

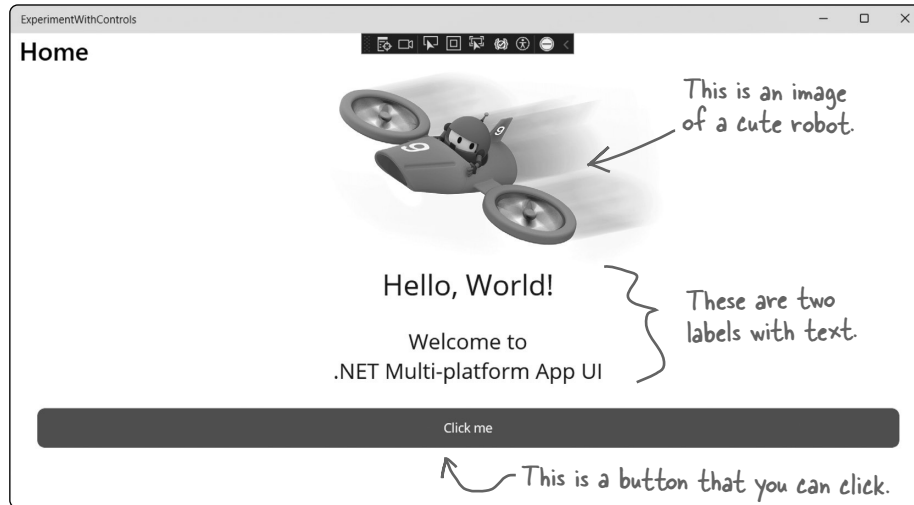
Don't worry about memorizing the XAML in this project. You'll pick it up throughout the book.

This Do this! and these exercises are all about getting some practice using XAML to build a UI with controls. You can always refer back to it when we use these controls in projects later in the book.

Create a new app to experiment with controls

Do this!

Go back to Visual Studio and **create a new .NET MAUI project**, just like you did in Chapter 1. Name your project **ExperimentWithControls**. Run your new .NET MAUI app. It will pop up a window with a picture of a cute robot, text that says *Hello, World!*, and smaller text that says *Welcome to .NET Multiplatform APP UI*, and finally a button with the label *Click me*.



Editing XAML and expanding or collapsing tags in VSCode works just like Visual Studio.

Now go back to Visual Studio and **double-click the file MainPage.xaml** to open it. Use the expand/collapse buttons in the left margin to collapse the `<Image>`, `<Label>`, and `<Button>` tags. Each of those tags corresponds to one of the controls in your app.

```

1  <?xml version="1.0" encoding="utf-8" ?>
2  <ContentPage xmlns="http://schemas.microsoft.com/dotnet/2021/maui"
3      xmlns:x="http://schemas.microsoft.com/winfx/2009/xaml"
4      x:Class="ExperimentWithControls.MainPage">
5
6      <ScrollView>
7          <VerticalStackLayout
8              Padding="30,0"
9              Spacing="25">
10             <Image.../>
15             <Label.../>
16             <Label.../>
20             <Button.../>
21         </VerticalStackLayout>
26     </ScrollView>
33 </ContentPage>

```

This `<Image>` tag displays the picture of the robot in an `Image` control.

These two `<Label>` tags create `Label` controls that display the two lines of text.

This `<Button>` tag adds the `Button` control to the page.

Click here to collapse or expand a tag.

The XAML for your MAUI page starts with a `ContentPage` tag, which can contain a single control—in this case, it's a `ScrollView`, which scrolls its content and displays a scrollbar on the side.

A `ScrollView` contains a single control. Yours contains a `VerticalStackLayout`, which can contain multiple controls (like the `Image`, two `Labels`, and `Button` on your page) and displays them stacked on top of each other vertically.

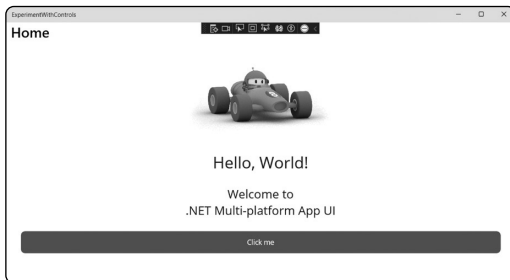
Explore your new MAUI app and figure out how it works

When you created your new .NET MAUI app, Visual Studio used a **template** to create the files for your app, substituting the name that you specified (*ExperimentWithControls*) in various lines in the files. Let's dig into the project that you created.

↖ Do this!

- 1 Create a new .NET MAUI project called ExperimentWithControls.**
Go back to Visual Studio and **create a new .NET MAUI project**, just like you did in Chapter 1. Name your project *ExperimentWithControls*.

- 2 Run your app and click on the button.**
When you run the app, you'll see the app window—it should look like this:



MAUI is cross-platform, which means you'll see the same app—whether you're running Windows or macOS.

You know you want to click the “Click me” button. Go ahead! The label on the button will change from “Click me” to “Clicked 1 time” and increment (or add one) every time you click the button.



If your app doesn't pause on the breakpoint, make sure you're starting it with debugging. Run the app by pressing F5 or choosing Start Debugging from the Debug (Visual Studio) or Run (VSCode) menu

- 3 Investigate how the counter on the button works.**
Go to the Solution Explorer, expand *MainPage.xaml*, and **open MainPage.xaml.cs**. Find the line that has the statement `count++`; and **place a breakpoint** on it.

```
0 references
12 private void OnCounterClicked(object sender, EventArgs e)
13 {
14     count++;
15
16     if (count == 1)
17         CounterBtn.Text = $"Clicked {count} time";
18     else
19         CounterBtn.Text = $"Clicked {count} times";
20
21     SemanticScreenReader.Announce(CounterBtn.Text);
22 }
```

The C# code for a page in your MAUI app is called *code-behind*. The XAML code and the C# code in the code-behind file work together to make your page work.

Before you go to the next step, read the code. Can you figure out how the button works?

4 Click on the button and step through the code.

Add a watch for the `count` variable, just like you did earlier in the chapter. Then use “Step Over” (F10) to step through the code. Here’s what the `OnCounterClicked` event handler method does:

- ★ First it executes `count++` to increment (or add one to) the `count` variable.
- ★ Next it uses an `if` statement to check if the `count` variable equals 1. If it does, then it sets the button’s text to “Clicked 1 time.”
- ★ If it doesn’t equal 1, it sets the button’s text to “Clicked {count} times”—you’ll learn more about exactly what the `$` dollar sign and {brackets} do in Chapter 5 (it’s called *string interpolation*).

5 Click on the button and step through the code.

The program should pause on the breakpoint, just like you saw earlier in the chapter:

```

12 private void OnCounterClicked(object sender, EventArgs e)
13 {
14     count++;
15
16     if (count == 1)
17         CounterBtn.Text = $"Clicked {count} time";
18     else
19         CounterBtn.Text = $"Clicked {count} times";
20
21     SemanticScreenReader.Announce(CounterBtn.Text);
22 }
    
```

This “if” statement sets the text on the Count button to “time” if count equals 1, or “times” if it has any other value.

Add a watch for the `count` variable, just like you did earlier with the `OperatorExamples` console app. It should start out with the value 0. Press the Step Over button or F10 to go to the next statement.

Name	Value	Type
count	0	int

The count variable starts with the value 0. After the “count++” statement is executed, the new value is 1. Each time you click the button, count++ increases the value of the count variable by 1.

Keep stepping through the code. The `if` statement checks whether the `count` value is equal to 1. If it is, it executes this statement, which updates the text on the button:

```
CounterBtn.Text = $"Clicked {count} time";
```

Go back to the window with the XAML code. Find this line:

```
<Button
    x:Name="CounterBtn"
```

This is the `x:Name` property. It gave the button the name “CounterBtn” that you can use in your C# code.

Every control can have a name. The `x:Name` property sets the name of the control—in this case, the button is named `CounterBtn`—and your C# code can use that name to make the control do things.



The XAML for Your Button Up Close

You've been editing the XAML code in your *MainPage.xaml* file—are you starting to get comfortable with it? This is a great time to take a closer look at the part of your XAML that displays the button.

Here's the **Button** tag. Take a look at each of its five properties. Can you figure out what they all do?

```
<Button
  x:Name="CounterBtn"
  Text="Click me"
  SemanticProperties.Hint="Counts the number of times you click"
  Clicked="OnCounterClicked"
  HorizontalOptions="Center" />
```

The x:Name property gives your control a name you can use in your code.

The first property is `x:Name`, which sets the name of the control so you can use it in your C# code:

```
x:Name="CounterBtn"
```

You just saw a control name in action. When you clicked the button, the event handler method executed this statement to set the button's text, using the name `CounterBtn` set by the `x:Name` property:

```
CounterBtn.Text = $"Clicked {count} time";
```

This line uses the `CounterBtn` name to update the text displayed on the button.

The Text property determines the text that's displayed on the button.

The XAML for a Buttons control has lots of options to change its appearance—like this next property:

```
Text="Click me"
```

The button displays “Click me” when you first run the app. That line of code in the method changes the text to “Clicked 1 time” the first time you click it, then “Clicked 2 times” when you click it again. That line of code starts with the name of the control (`CounterBtn`), followed by a period, followed by `Text`, the name of the property.

SemanticProperties help you make your apps accessible.

When we create our apps, we want everyone to be able to use them—and that includes people with disabilities.

A **screen reader** is a tool that lets people who are blind, visually impaired, or have learning disabilities or other conditions that interfere with their ability to read use our visual apps. Semantic properties help your app work with a screen reader.

A screen reader is an accessibility tool for people with visual, learning, or other disabilities—just like a wheelchair is an accessibility tool for people with mobility-related disabilities. They're both really important for helping to make everyday things more accessible to everyone.



The XAML for Your Button Up Close



Use a screen reader to experiment with the `SemanticProperties.Hint` property.

The best way to make your apps accessible is to use them the way someone with accessibility issues would—in this case, using a screen reader built into your operating system.

- **In Windows, start the Narrator app.** You can run it from the Start menu, or use Windows logo key + Ctrl + Enter to turn Narrator on or off, and Windows logo key + Ctrl + N to bring up Narrator settings. Narrator will display a window with an overview of how Narrator works. It will also start to read the contents of that window, displaying a box around the section of the window that it's reading. You can go back to that window to turn off Narrator.
- **In MacOS, start the VoiceOver utility.** It lives in the Applications/Utilities folder, but if your keyboard has Touch ID, the easiest way to turn it on or off is to press and hold the Command key while you quickly press Touch ID three times. By default the VoiceOver utility displays a welcome dialog—press the V key or click the Use Voiceover button to start VoiceOver.

Once you have Narrator or VoiceOver running, switch to your app window. You'll hear a voice telling you details about what's on the screen. People with visual impairments often have trouble using a mouse, so they use the keyboard to interact with apps—and you'll do the same thing. **Press the Tab key** to navigate to the Click Here button. The screen reader will announce that you are on a button. Listen closely—you'll hear it speak the `SemanticProperties.Hint` value: "Counts the number of times you click."

Press Enter to click the button. Your app will execute code that includes this statement:

```
SemanticScreenReader.Announce(CounterBtn.Text);
```

When it does, the screen reader will announce the contents of the button ("Clicked 1 time").

The `Clicked` property tells your app what event handler method to run when the button is clicked.

Take a look at the next property in the button's XAML code:

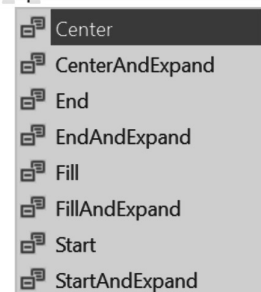
```
Clicked="OnCounterClicked"
```

When you click the button, your app uses that property to figure out which method to run. You saw this in action when you placed a breakpoint on the first line of that method.

The `HorizontalOptions` property centers your button.

When you run your app, the Click Me button is centered in the middle of the window. Go back to the code editor, select the word **Center** in that line of XAML code, and type **C**. Visual Studio will display an IntelliSense pop-up with all of the different options. Try selecting Start or End, then run your app again—now the button will be displayed on the left or right side of the window. Experiment with all of the different horizontal options for Button control.

```
HorizontalOptions="C" />
```



add a control to enter some text

Add an Entry control to your app

An **Entry control** displays a box for the user to enter text. You'll add one to your app, and you'll use a really useful tool in Visual Studio to do it: the **Toolbox window**. The Toolbox is a feature of Visual Studio that makes it easy to add controls to your app:

1. Stop your app, then open the MainPage.xaml editor window in Visual Studio.
2. Place your mouse cursor just after the closing `</>` bracket at the end of your Button control tag, then **press Enter three times** to add three blank lines. Click on the second line that you just added, so there's a blank line above your mouse cursor and another blank line below it.
3. Open the Toolbox window in Visual Studio (if it isn't already open) by **choosing Toolbox from the View menu**.
4. **Double-click Entry** in the Toolbox window. Visual Studio will automatically add an `<Entry>` tag at your cursor location, on that blank line you added.

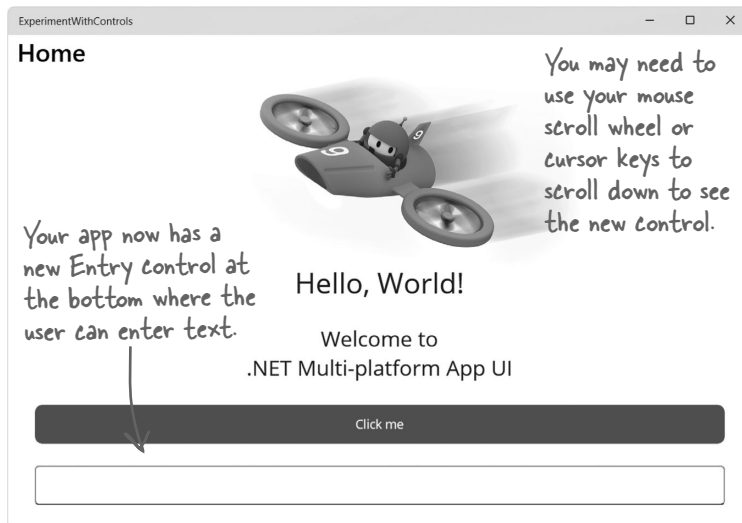
If you have trouble with the Toolbox, you also can **type the XAML code** directly into the editor.

Here's what you should see in your XAML code:

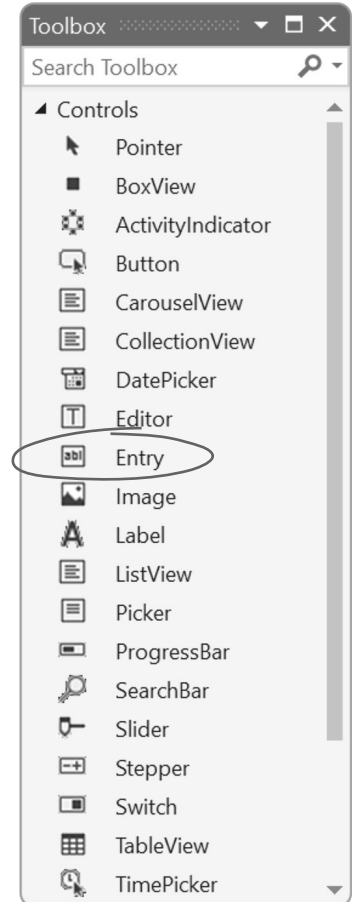
```
<Button
  x:Name="CounterBtn"
  Text="Click me"
  SemanticProperties.Hint="Counts the number of times you click"
  Clicked="OnCounterClicked"
  HorizontalOptions="Fill" />
```

```
<Entry Placeholder="" />
```

Now run your app. Congratulations, you just added a control for entering text!



Visual Studio's Toolbox window helps you add new controls to your XAML code. If you don't see the Toolbox window, choose "Toolbox" from the View menu to display it.



If you're using VSCode, it doesn't have a Toolbox, so you'll need to type the XAML in by hand.



The screenshot and XAML for the app are from the MAUI template that's part of .NET 9. If you're using a different version of .NET, you may see a different image and slightly different XAML.

Add properties to your Entry control

Let's make your Entry control a little more usable by adding **placeholder text**, or text that appears in a lighter color to help the user understand what they're supposed to enter.

Edit the XAML code for your Entry control to **add a Placeholder property**. And since we always want our apps to be accessible to people who use screen readers, **add a SemanticProperties.Hint property** too. Notice that when you add the properties, they show up in Visual Studio's typeahead pop-up window, making it easier for you to add them.

Your Entry tag should look like this:

```
<Entry
    Placeholder="Enter some text"
    SemanticProperties.Hint="Lets you enter some text" />
```

Now run your app—you'll see a new Entry control at the bottom. The placeholder text will appear as ("Enter some text" in a lighter color, and will disappear as soon as you type text into it.



If you don't see the control at the bottom of the window, use the cursor keys or mouse scroll wheel to scroll down to it.



At the time we're writing this, VSCode does not have a Toolbox, so you'll need to type all of the XAML by hand. Make sure it matches the XAML in the book exactly, or the app won't work.

there are no Dumb Questions

Q: Why did the Entry control get added to the bottom of my app? How did it know where in the window to display?

A: When you created a new .NET MAUI app, Visual Studio used a template that generated the XAML code for the main page in the *MainPage.xaml* file. This file contains a set of **nested tags**, or tags that contain other tags—so one tag's start and end appear after the start and before the end of another tag. Each of these tags *creates a specific kind of control* that determines how the page is displayed.

The outermost tag in your app's XAML is a `<ContentPage>` opening tag, which defines a single view that contains the rest of the page. If you scroll down to the bottom of the file, you'll see the closing `</ContentPage>` tag. Right inside that `<ContentPage>` is a `<ScrollView>` tag—everything between the opening `<ScrollView>` and closing `</ScrollView>` tags defines contents that will automatically display a scrollbar that lets you scroll up and down if it's too long for the page. The `<ScrollView>` tag contains a `<VerticalStackLayout>` tag, with a matching `</VerticalStackLayout>` closing tag at the bottom. A `VerticalStackLayout` can contain a series of controls, one after another. Each of those controls will be displayed on the page in a vertical stack, in the order that they appear in the file.

So since the Entry control is at the bottom of the file just above the closing `</VerticalStackLayout>` tag, it will appear at the bottom of the page. And because it's nested inside the `<ScrollView>...</ScrollView>` tags, if you make your window shorter than the height of the page, you'll be able to scroll down to it.

Make your Entry control update a Label control

Your app already has two Label controls. Let's add a third one and make it display everything the Entry does, so when you enter or update text in the Entry it automatically updates the Label.

1 Use the Toolbox to add a new Label control to the bottom of your page.

When you drag the Label out of the Toolbox, it will have an empty Text property:

```
<Label Text="" />
```

Change the Text property to make it display text. Then give it a SemanticProperties.Description property. This is what will get read aloud if your user is using a screen reader:

```
<Label Text="Here's what you typed:"  
      SemanticProperties.Description="Here's what you typed:" />
```

You can add line breaks between properties to make them easier to read.

2 Use the Toolbox to add a *second* Label control under the one you just added.

Every time the user changes the text in your Entry control, the app will update this new Label to show the text that they typed. Drag a new Label control out of the Toolbox and drop it in your XAML code between the Label control that you just added and the closing `</VerticalStackLayout>` tag. Then set its properties:

- ★ You'll be writing code to set the Label text, so delete the Text property.
- ★ Since you're going to write code that updates the Label, you'll need to give it a name. Use an `x:Name` property to name it `EnteredText`:
`x:Name="EnteredText"`
- ★ Keep making your app accessible by adding a description for people using a screen reader:
`SemanticProperties.Description="The text that the user entered"`

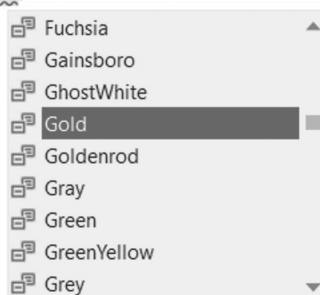
Your new Label should look like this:

```
<Label x:Name="EnteredText"  
      SemanticProperties.Description="The text that the user entered" />
```

3 Give your label a background color.

Add a `BackgroundColor` property. When you start typing, Visual Studio will pop up an IntelliSense window. Choose Gold for the background color.

```
<Label x:Name="EnteredText"  
      SemanticProperties.Description="The text that the user entered"  
      BackgroundColor="" />
```



You can use Visual Studio's IntelliSense to help you add properties. Once you add it, you'll see a box with a preview of the color in the XAML editor.

```
BackgroundColor= "Gold" />
```



An update to Visual Studio since we took this screenshot may have removed Margin from the Properties window. If you don't see it (or any other property), just type the XAML so it matches.

4

Use the Properties window to add a bottom margin.

So far you've been adding properties by writing XAML code by hand. Luckily, Visual Studio has some useful tools to help you edit your XAML. The Properties window gives you an easy way to edit the properties on your controls. Click the XAML for your Label control so the cursor is somewhere between the tags. Go to the Properties window (if you don't see it, use the View menu to display it) and find Margin. Enter 20 for the lower margin to give it a 20 pixel margin (where a pixel is 1/96th of an inch on an unscaled screen).



When this square turns black (or circle if you're using macOS), it means that the property has a value set. You can click it to see a menu.

Your property should now look like this:

```
<Label x:Name="EnteredText"
      SemanticProperties.Description="The text that the user entered"
      BackgroundColor="Gold" Margin="0,0,0,20"/>
```


Enter 20 for the bottom margin to give 20 units of space between the label and the bottom of the page.

5

Add an event handler method.

Back in Chapter 1, you used event handler methods so your animal matching game could respond to mouse clicks and timer ticks. Now you know more about C# methods—this is a good chance to apply that knowledge by creating a new event handler method that updates the EnteredText control when the user types in the Entry control. Add a TextChanged property to your Entry control. When it comes time to enter the value, Visual Studio will suggest the value **<New Event Handler>**:

```
<Entry
  Placeholder="Enter some text"
  SemanticProperties.Hint="Lets you enter some text"
  TextChanged=""
/>
```

 <New Event Handler>



Don't forget—VSCode may not have this feature yet, so you might need to type the `Entry_TextChanged` method in by hand.

Press Return or use the mouse to accept the suggestion—this will cause Visual Studio to **add a new event handler method called `Entry_TextChanged` automatically**. You probably also noticed that it also displayed this message when you were adding the event handler:

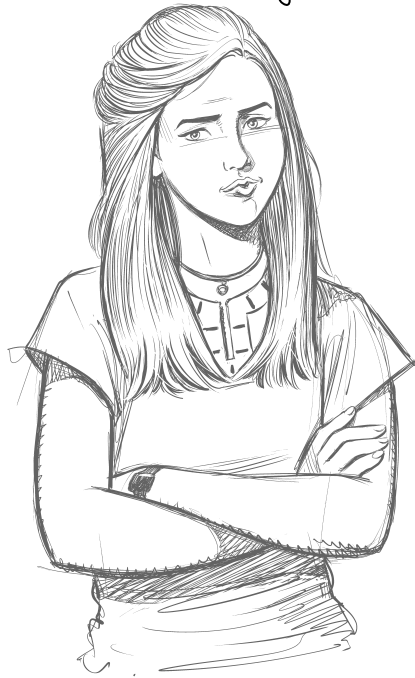
Bind event to a newly created method called 'Entry_TextChanged'. Use 'Go To Definition' to navigate to the newly created method.

Right-click on `Entry_TextChanged` and choose `Go To Definition`. This will open up `MainPage.xaml.cs` and jump directly to the method that Visual Studio added. Add this line of code to the method:

```
private void Entry_TextChanged(object sender, TextChangedEventArgs e)
{
    EnteredText.Text = e.NewTextValue;
}
```

If you're using VSCode, open `MainPage.xaml.cs` and add this just above the last closing bracket.

Now **run your app**. You should see a label that says “Here's what you typed:” followed by a gold-colored label. Click on the Entry control and type some text—it will appear in the gold-colored label immediately.



Why do I need to add those semantic hints? It's not like you can see them. Does it **really matter** if they're not there?

When you pay attention to accessibility, it makes your app—and your code!—better.

When you're building apps, it's always a great idea to create them so as many people can use them as possible, including people with disabilities—and not just because it's the right thing to do. Building accessibility into your apps **actually helps you become a better developer**. Really!

If you want to be a great developer, you need to get practice writing code: writing code is a skill, and the more code you write, the better you get at it. But there's more to being a developer than “just” coding.

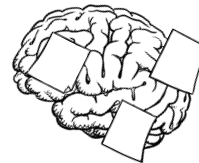
One of the biggest challenges that very experienced developers face is deciding exactly what they want to build. In fact, a lot of programmers will talk about the challenges of “building the software right and building the right software.” One of the most common problems in software engineering is building a great product that doesn't do what your users need.

That's where accessibility can help you. Building accessible code well means taking the time to **really understand** how people with disabilities will use your app. Taking the time to understand and empathize with them will help you build your app better—and it's great practice for skills that will help you build the right software.

One of our big goals with this book is to help you learn important skills that will help you become an all-around great developer. Understanding your users is a really important skill, and paying attention to accessibility is a great way to get better at it!

Using a screen reader is an effective way to get a better feel for accessibility.

Make it Stick



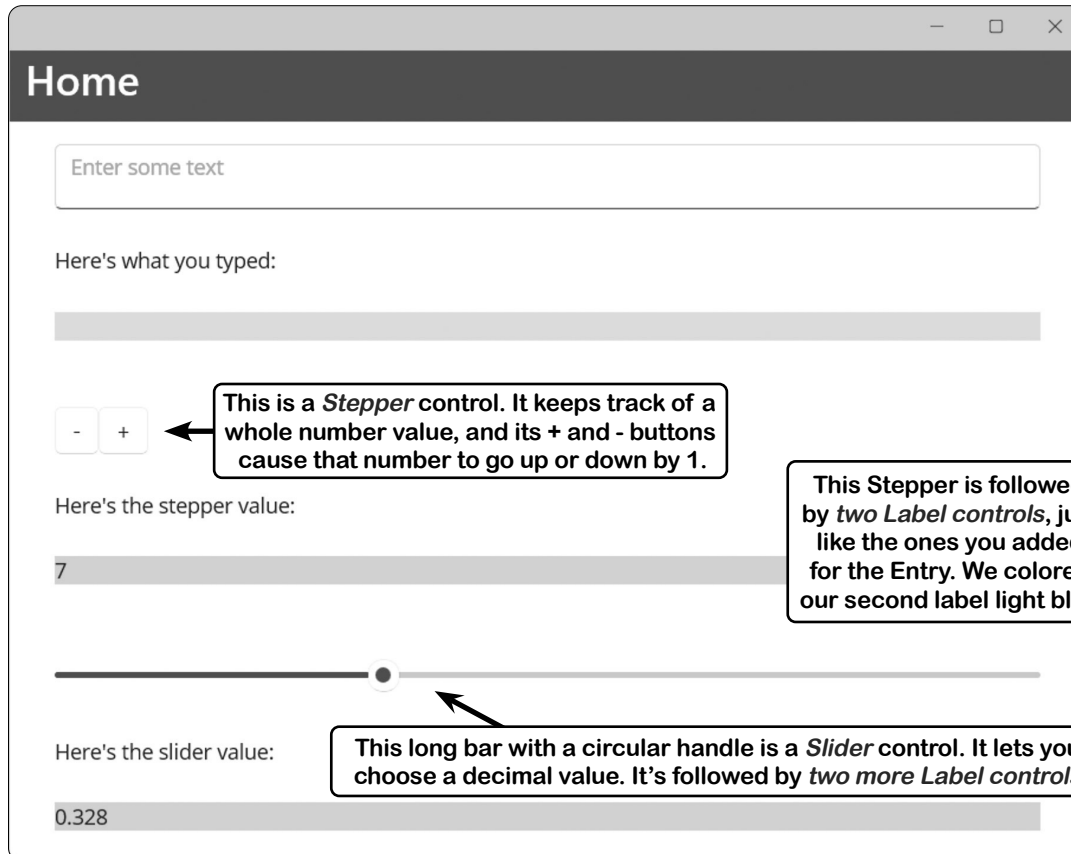
Here's a great way to get accessibility ideas to stick in your brain—especially if you don't have a disability. Turn on your screen reader, then **leave it on** while you code or do other work. Once you're used to it, **close your eyes** and keep working. Can you work using just the screen reader?

Don't forget, it's absolutely fine to peek at the solution—especially if you're using VSCode and trying to figure out how to add the event handler methods.

dive into c# code

Exercise

You added Entry and Label controls to your app—and Visual Studio's Toolbox window, Properties window, and IntelliSense helped you. Can you add six more controls to your app to let your user enter numeric values?



Use the Toolbox window, Properties window, and Visual Studio editor to **add a Stepper control, two Label controls, a Slider control, and two more Label controls** to your app (if you're using VSCode, add them manually).

The two Label controls that display the values should have the `BackgroundColor` property set to `LightBlue`. **Name them `StepperValue` and `SliderValue`**. Make sure you **add `SemanticProperties.Description` properties**.

You want your app to automatically update the `StepperValue` control every time the stepper value changes, so **add a `ValueChanged` event handler** to the Stepper control. Add this line of code to the event handler:

```
StepperValue.Text = e.NewValue.ToString();
```

Then add a `ValueChanged` event handler **to the Slider control**. It should be identical, except that it updates the `SliderValue` label instead of the `StepperValue` label. Don't forget to **add `SemanticDescription.Hint` properties** to your Stepper and Slider controls.

If you're using VSCode, you'll need to add the `Stepper_ValueChanged` and `Slider_ValueChanged` methods manually. They're just like `Entry_TextChanged`, just replace "Text" with "Value" in the first line. Visual Studio's Toolbox automatically adds these properties to the Stepper tag: `Minimum="0"` `Maximum="10"` `Increment="1"`—and these to the Slider tag: `Minimum="0"` `Maximum="1"`.

Exercise Solution

Here's the XAML to add the six controls to *MainPage.xaml*:

```
<Label x:Name="EnteredText"
    SemanticProperties.Description="The text that the user entered"
    BackgroundColor="Gold" Margin="0,0,0,20"/>
<Stepper Minimum="0" Maximum="10" Increment="1"
    SemanticProperties.Description="Lets you enter a whole number"
    ValueChanged="Stepper_ValueChanged" />
<Label
    Text="Here's the stepper value:"
    SemanticProperties.Description="Here's the stepper value" />
<Label x:Name="StepperValue"
    SemanticProperties.Description="The number the user chose with the Stepper"
    BackgroundColor="LightBlue" Margin="0,0,0,20"/>
<Slider Minimum="0" Maximum="1" ValueChanged="Slider_ValueChanged" />
<Label
    Text="Here's the slider value:"
    SemanticProperties.Description="Here's the slider value" />
<Label x:Name="SliderValue"
    SemanticProperties.Description="The number the user chose with the Slider"
    BackgroundColor="LightBlue" Margin="0,0,0,20"/>
</VerticalStackLayout>
```

This is the Label control that was already in your XAML code—make sure you put your six new controls below it.

These are the default properties when you drag the Stepper out of the Toolbox. Try experimenting with them.

You can add this ValueChanged property just like you did with TextChanged on your Entry control.

Here's the Slider control. It has the default properties, plus a ValueChanged property.

Here's the Label that displays the Slider value. It works exactly like the Label you used to show the value in the Entry control.

This is the closing VerticalStackLayout tag that was already in your XAML code—make sure you put your six new controls above it.

Here are the event handler methods to add to *MainPage.xaml.cs*:

```
private void Stepper_ValueChanged(object sender, ValueChangedEventArgs e)
{
    StepperValue.Text = e.NewValue.ToString();
}
private void Slider_ValueChanged(object sender, ValueChangedEventArgs e)
{
    SliderValue.Text = e.NewValue.ToString();
}
```

The two event handlers for the Stepper and Slider controls update the Label.

In the exercise instructions, we gave you this line of code:

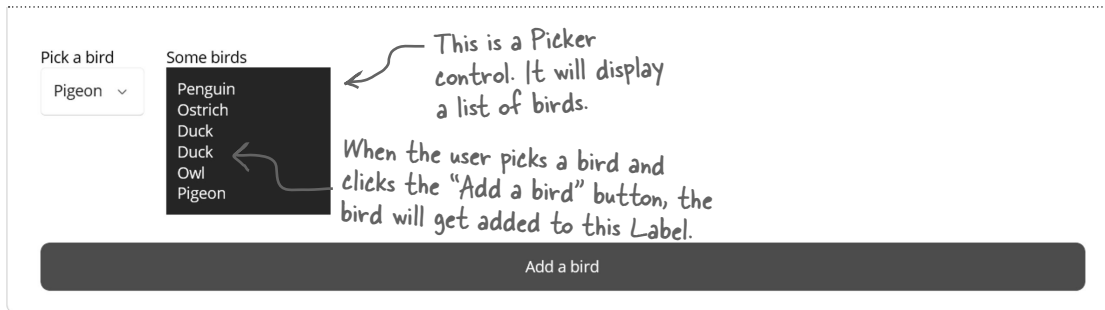
```
SliderValue.Text = e.NewValue.ToString();
```

What do you think .ToString() does?

Here's a hint: Stepper and Slider controls can only provide numeric values, but Labels can only display text.

Combine horizontal and vertical stack layouts

In this last part of the exercise, you'll add a **Picker control**, which displays a list of items that you can pick from. You'll also use a Label control to display the values that were picked. Here's what it will look like:



Notice how the Label and Picker controls are next to each other? You'll get that layout by using a **HorizontalStackLayout control**. It works just like the VerticalStackLayout control, which causes all of the controls you've added to your app so far to be stacked vertically on top of each other, except instead they get stacked horizontally next to each other.

You'll nest one Layout inside another

We'll use **nesting**—where one layout control lives inside another one—to create a more complex layout.

Here's how it will work:

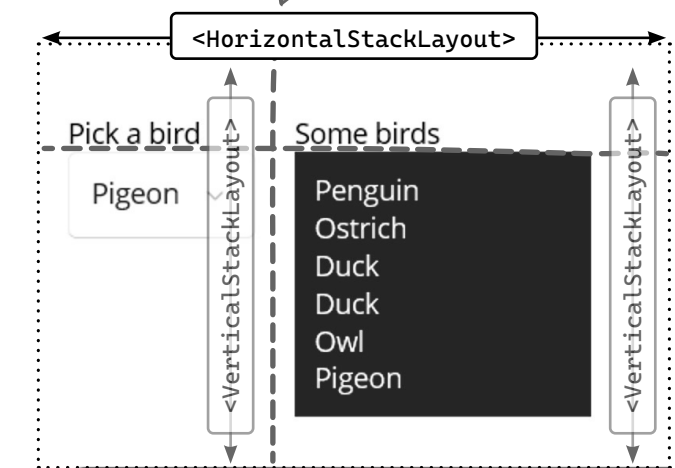
This HorizontalStackLayout will get nested inside the outer VerticalStackLayout that's used to lay out the entire page.

```
<HorizontalStackLayout>
  <VerticalStackLayout>
    <Label Text="Pick a bird" ... />
    <Picker x:Name="BirdPicker" ... />
  </VerticalStackLayout>

  <VerticalStackLayout>
    <Label Text="Some Birds" ... />
    <Label x:Name="Birds" ... />
  </VerticalStackLayout>
</HorizontalStackLayout>
```

This nested VerticalStackLayout contains a Label that says "Pick a bird" and a Picker control named BirdPicker, stacked vertically.

You'll use this HorizontalStackLayout to position two VerticalStackLayout controls next to each other.



This nested VerticalStackLayout contains a Label that says "Some birds" and a Label named Birds that will get updated when the user clicks the button, also stacked vertically.

Add a Picker control to display a list of choices

A **Picker control** displays a list of items in a dropdown so the user can pick one of them. Let's add one to your app.

1 Add the XAML for a Picker control and a Label for it to update.

You've already seen how a `VerticalStackLayout` control lets you stack controls on top of each other. You can also stack controls horizontally by adding a **HorizontalStackLayout control**.

Go ahead and **add this XAML code** just above the closing `</VerticalStackLayout>` tag. You can type it all or use the Toolbox. When you add the `Clicked` event for the button, **press Tab** to let Visual Studio generate an event handler method for you, just like you did earlier (add the method manually in VSCode).

```
<HorizontalStackLayout Spacing="20">
    <VerticalStackLayout>
        <Label Text="Pick a bird" SemanticProperties.Description="Picks a bird" />
        <Picker x:Name="BirdPicker" />
    </VerticalStackLayout>
    <VerticalStackLayout>
        <Label Text="Some birds"
            SemanticProperties.Description="A list of birds" />
        <Label x:Name="Birds"
            Padding="10" MinimumWidthRequest="150"
            TextColor="White" BackgroundColor="DarkBlue"
            SemanticProperties.Description="Shows the added birds" />
    </VerticalStackLayout>
</HorizontalStackLayout>

<Button x:Name="AddBird" Text="Add a bird" Margin="0,0,0,20"
    SemanticProperties.Hint="Adds a bird" />
```

This <Button ... /> tag should be just above the closing </VerticalStackLayout> tag that's already in MainPage.xaml.

2 Initialize the Picker with a list of birds.

Open the `MainPage.xaml.cs` file and find the `MainPage` method at the top. This method gets run every time the page loads. Insert two lines after `InitializeComponent();` and **add this code**.

```
public MainPage()
{
    InitializeComponent();
    BirdPicker.ItemsSource = new string[] {
        "Duck",
        "Pigeon",
        "Penguin",
        "Ostrich",
        "Owl"
    };
}
```

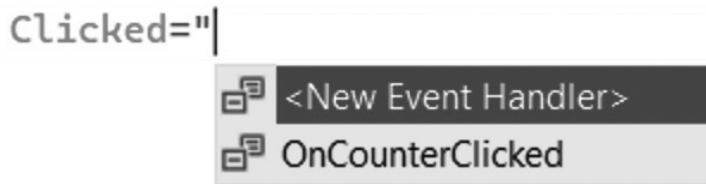
Put your code at the end of the MainPage method.

You used the x:Name property to name your Picker control "BirdPicker"—this sets the list of items in the picker that get displayed when the user clicks on it.

Open the `MainPage.xaml.cs` file and add this code to the `MainPage` method. Be careful with the square and curly braces, quotes, and commas.

3 Fill in the event handler for the Button control.

The XAML we gave you for the Button control didn't include a Clicked event handler. Use Visual Studio's IntelliSense pop-up to add a new event handler to the C# code, just like you did with the Entry control:



! Don't forget—VSCode may not have this feature yet, so you might need to type the `AddBird_Clicked` method in by hand.

Since you used the `x:Name` property to name your Picker control `AddBird`, Visual Studio created an empty event handler method called `AddBird_Clicked`:

```
private void AddBird_Clicked(object sender, EventArgs e)
{
}

```

If you're using VSCode, you might need to open `MainPage.xaml.cs` and add this entire method. Put it just above the bottom closing bracket in the file.

Add this line of code to the `AddBird_Clicked` method:

```
private void AddBird_Clicked(object sender, EventArgs e)
{
    Birds.Text = Birds.Text + Environment.NewLine + BirdPicker.SelectedItem;
}

```

Take a closer look at the line of code—let's break down exactly what it does.

1. The line starts with `Birds.Text = ...` which means it's setting the text in the Bird label.
2. The text is being set to `Birds.Text +` followed by additional things—this means it's going to take whatever is in the Label and **append text** to it, or add additional text to the end.
3. The first thing that gets appended is `Environment.NewLine`, which adds a line break. The Label control will display **multiline text**, adding a line break every time it sees a line break.
4. After the line break, it appends `BirdPicker.SelectedItem`—this is the item that's currently selected in the Picker control.

4 Run your app and use your new Picker control.

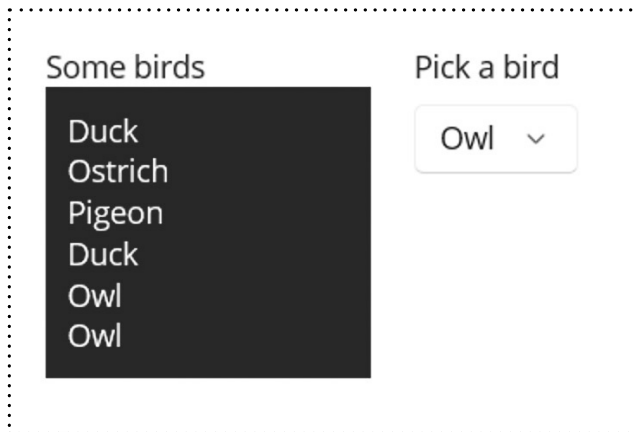
Scroll to the bottom of the app, choose a bird from the Picker, and click the Add a bird button—it will get added to the Label that contains the birds. Select a few more birds and add them.



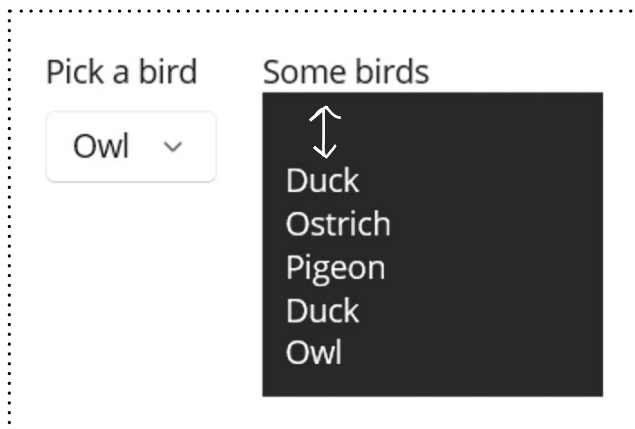
Hold on. My app doesn't match the first screenshot that you showed us. It looks like **there's SOME EXTRA SPACE** at the top of the label! The code has a bug.

You're right! The app doesn't match the screenshot.

Take a look at the screenshot we showed you earlier:



Run your app and try adding those same birds. When you get to the first owl, you'll see extra space at the top of the label:



Oops! It looks like we've got some extra space at the top of the label that shows the birds that you picked.

Looks like we've got a bug. Time to put on your Sherlock Holmes cap. **Let's sleuth out this bug!**



The Case of the Extraneous Space

Understanding a bug is the first step in fixing it.

In Chapter 1, we looked at the code carefully and found several clues to help us solve the Case of the Unexpected Match. But as you keep going through this book, your apps will get longer and longer, and while looking at the code is a good start, it may not always be the best way to figure out what's causing a bug.

Luckily, the Visual Studio debugger is a great tool for that. (That's why it's called a debugger: it's a tool that helps you get rid of bugs!)

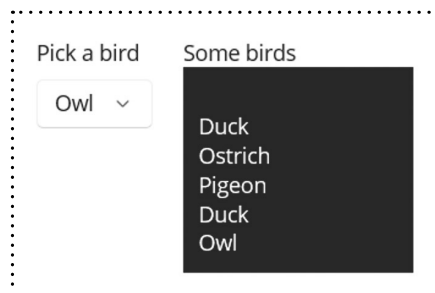
Reproduce the bug

It seems obvious that there's a problem. But as Sherlock Holmes once said, "There is nothing more deceptive than an obvious fact." When you're sleuthing out bugs, you can't just rely on what seems obvious. You need to confirm for yourself exactly what's going on. The way to do that is to **reproduce the bug**.

Stop your app. Make sure it's not running, so you've got a fresh start. Then do this:

1. Start your app again.
2. Pick Duck and click the "Add a bird" button.
3. Pick Ostrich and click the "Add a bird" button.
4. Pick Pigeon and click the "Add a bird" button.
5. Pick Duck and click the "Add a bird" button.
6. Pick Owl and click the "Add a bird" button.

Your app should now look exactly like the screenshot:



Now restart your app, then try it again with different birds. You should still see extra space at the top of the label. You can make the bug happen over and over again, at will. That means the problem is **reproducible**: you can follow a set of steps to make it happen. Reproducing a bug is a great first step to fixing it.

Before you go on, can you sleuth out what's causing the extra space to get added?

**"There is nothing
more deceptive than
an obvious fact."
– Sherlock Holmes**



Sleuth it Out

Every good investigation starts by identifying a list of suspects

When you're tracking down a bug, what's the first thing you should do? You could start placing breakpoints in the code...but where? **The first step in debugging is thinking.** Look at your code, think about how it works, and try to imagine where the bug might be. That will help you figure out where to put your breakpoints.

So let's think through the code. It starts with a button—and the button calls a method:

```
<Button x:Name="AddBird" Clicked="AddBird_Clicked" Text="Add a bird"
        Margin="0,0,0,20" SemanticProperties.Hint="Adds a bird"/>
```

All of the code to add the bird to the label is in that **AddBird_Clicked** method. Now we have a suspect!

Remember, if your app doesn't pause on the breakpoint, make sure you're starting the app with debugging. Run the app by pressing F5 or choosing Start Debugging from the Debug (Visual Studio) or Run (VSCode) menu.

IDE Tip: Using the debugger

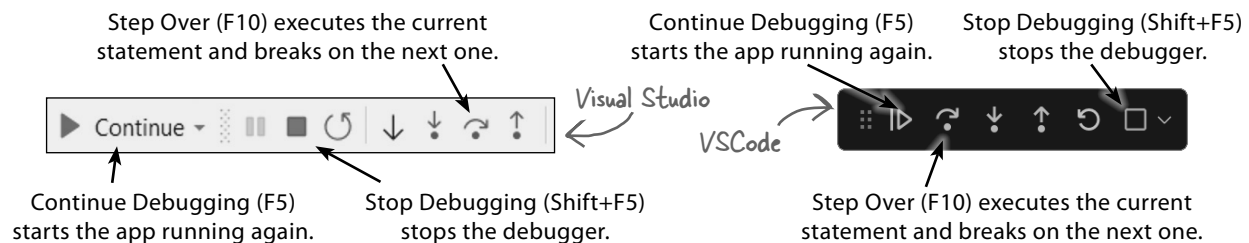
You're going to be using the debugger a lot in this book! We've walked you through it a few times, but as you get further in the book and write more and more code, you should feel comfortable using the debugger on your own.

Let's start with **a few tips** to help you get comfortable debugging your code:

- ★ Think before you debug. Read through your code. Understand how it works (and not just how *you think it works*).
- ★ Use the Watch window, Locals window, and hovering over variables to keep track of their values. They all do the same thing—show you the value of a variable—so you can decide which one you feel most comfortable with.
- ★ Don't be afraid to restart your app. Stop and start your code frequently—every time you run your code, you're *running an experiment*. Run it as many times as it takes to understand what's going on.

Here's a handy **list of useful debugger commands**. They may feel strange at first, but they'll be second nature soon:

- ★ When you press the triangle Run button in the toolbar or choose Start Debugging (F5), Visual Studio starts running your code in the debugger. You can place a breakpoint whether or not the debugger is running.
- ★ To place a breakpoint, click on a line of code and choose Toggle Breakpoint (F9) from the Debug menu.
- ★ When your code hits a breakpoint, it stops running so you can inspect variables.
- ★ When Visual Studio breaks on a breakpoint, the toolbar shows you the commands you can use to keep executing. Debugging code can be a little weird to get used to if you haven't done it before, so try sticking to just these four commands—here's where you'll find them in the IDE's toolbar, along with their keyboard shortcuts:





Sleuth it Out

Add a breakpoint and start debugging the code

Now that we have a suspect, let's catch it in the act. Add a breakpoint to the line in the `AddBird_Clicked` method:

```
private void AddBird_Clicked(object sender, EventArgs e)
{
    Birds.Text = Birds.Text + Environment.NewLine + BirdPicker.SelectedItem;
}
```

Now **run your code**. Pick a bird, then click the “Add a bird” button. The debugger stops on your breakpoint. Next, **add a watch for `Birds.Text`**, just like you did earlier in the chapter. The value should be **null**:

Name	Value	Type
Birds.Text	null	string

Then **step over that line of code** (F10) to run it. You should see this value:

Name	Value	Type
Birds.Text	“\r\nPigeon”	string

The value of `Birds.Text` is a string: `\r\n` followed by the bird you picked. What do you think `\r\n` does?

NOTE: If you're using macOS, you'll see `\n` instead of `\r\n`.

Continue debugging (F5) to start your app running again. Pick a different bird and step over the line of code. Now have a look at the `Birds.Text` watch:

Name	Value	Type
Birds.Text	“\r\nPenguin\r\nOstrich”	string

Repeat the process a few more times: continue debugging, pick a bird, click the button, step over, check the watch. Eventually your `Birds.Text` value will look something like this (you'll see `\n` instead of `\r\n` on macOS):

“\r\nPenguin\r\nOstrich\r\nPigeon\r\nDuck\r\nOwl\r\nPigeon\r\nDuck\r\nOwl”

You've probably figured out by now that **the `\r\n` or `\n` is the line break**. The first time the `AddBird_Clicked` method is called, the Label text is empty (that's what the `null` value means), so when the app adds the current value (**empty**) plus a line break plus the bird, it adds an extra line break at the start of the string.

Now that we've found the culprit, we can fix the app. **Replace the `AddBird_Clicked` method** with this code, which uses a special method, **`String.IsNullOrEmpty`**, which checks if a string is empty:

```
private void AddBird_Clicked(object sender, EventArgs e)
{
    if (!String.IsNullOrEmpty(Birds.Text))
    {
        Birds.Text = Birds.Text + Environment.NewLine;
    }
    Birds.Text += BirdPicker.SelectedItem;
}
```

`String.IsNullOrEmpty(Birds.Text)` checks the value of `Birds.Text` and returns true if it's empty or false if it's not. The `!` in front of it reverses that value, so the line break is only added if `Birds.Text` is empty. You'll learn all about how a method can return a value in the next chapter.

Run your app again and add a few birds to the label—there's no more empty space above it. **Your app is fixed!**

The Picker keeps growing each time you add a bird. Can you figure out which property gives it a maximum height?



When I first spotted the bug in the app, it **seemed really weird**. But once I thought through the code and did some experimenting, I **found an explanation**.

There are no unexplainable mysteries in your code. Every bug has an explanation, even if it takes work to figure out what's going on and fix it.

Bugs can be weird! If you've been playing video games for a long time, you've probably experienced a few glitches, and some of them can be extremely odd. If you haven't seen any yourself, try searching the web for videos of game glitches—even the most polished game has bugs.

Every bug you see is *code behaving in a way you don't expect*. That's why bugs need sleuthing out. Bugs can be confusing, mysterious, and sometimes extremely frustrating. It's even tempting to think that something is fundamentally wrong, and the code will never work. Always remember that **every bug has an explanation**. Every bug is strange, but even a bug that appears to be a weird mystery is caused by something in your code—so you can fix it. Because like Sherlock Holmes once said, “It is a mistake to confound strangeness with mystery.”

Bullet Points

- You'll use many different **controls** to build your app's user interface (or UI). The UI is the part of the application that your user interacts with.
- The C# code for a page in a MAUI app is called **code-behind**. The XAML code and the C# code in the code-behind file work together to make the page work.
- The `x:Name` property gives your control a name you can use in your code.
- When you pay attention to **accessibility**, it makes your app—and your code!—better. **Semantic properties** help you make your apps accessible by providing descriptions and hints for people who use screen readers.
- In XAML you can have **nested controls**, or tags that contain other controls, so one control's start and end tag appear after the start tag and before the end of another tag.
- You can use nested **HorizontalStackLayout** and **VerticalStackLayout** controls to create more complex layouts.
- The first step in debugging is thinking: look at your code, think about how it works, and try to imagine where the bug might be.
- **Reproducing a bug** is an important tool that helps you fix it. When you're debugging, you're **running an experiment** every time you run your code. Run it as many times as it takes to understand what's going on.

Unity Lab #1

Explore C# with Unity

Welcome to your first **Head First C# Unity Lab**. Writing code is a skill, and like any other skill, getting better at it takes **practice and experimentation**. Unity will be a really valuable tool for that.

Unity is a cross-platform game development tool that you can use to make professional-quality games, simulations, and more. It's also a fun and satisfying way to **get practice with the C# tools and ideas** you'll learn throughout this book. We designed these short, targeted labs to **reinforce the concepts and techniques you just learned** to help you hone your C# skills. These labs are optional, but valuable practice... **even if you aren't planning to write games in C#**.

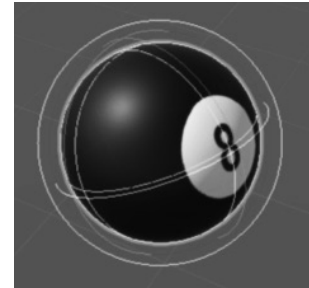
In this first lab, you'll get started with Unity. You'll get oriented with the Unity editor, and you'll start creating and manipulating 3D shapes. That will lay down a foundation to write code in the next lab.

Unity is a powerful tool for game design

Welcome to the world of Unity, a complete system for designing professional-quality games—both two-dimensional (2D) and three-dimensional (3D)—as well as simulations, tools, and projects. Unity includes many powerful things, including..

A cross-platform game engine

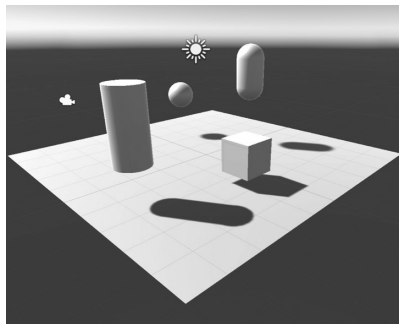
A **game engine** displays the graphics, keeps track of the 2D or 3D characters, detects when they hit each other, makes them act like real-world physical objects, and much, much more. Unity will do all of these things for the 3D games you build throughout this book.



A powerful 2D and 3D scene editor

You'll be spending a lot of time in the Unity editor. It lets you edit levels full of 2D or 3D objects, with tools that you can use to design complete worlds for your games. Unity games use C# to define their behavior, and the Unity editor integrates with Visual Studio to give you a seamless game development environment.

While these Unity Labs will concentrate on C# development in Unity, if you're a visual artist or designer, the Unity editor has many artist-friendly tools designed just for you. Check them out here: <https://unity.com/solutions/artist-designers>



An ecosystem for game creation

Beyond being an enormously powerful tool for creating games, Unity also features an ecosystem to help you build and learn. The Learn Unity page (<https://unity.com/learn>) has valuable self-guided learning resources, and the Unity forums (<https://forum.unity.com>) help you connect with other game designers and ask questions. The Unity Asset Store (<https://assetstore.unity.com>) provides free and paid assets like characters, shapes, and effects that you can use in your Unity projects.

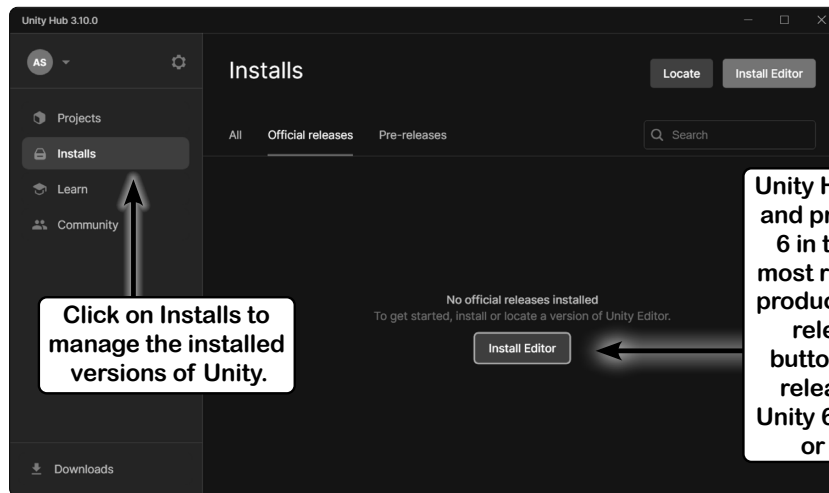
Our Unity Labs will focus on using Unity as a tool to explore C# and practicing with the C# tools and ideas that you've learned throughout the book.

The *Head First C#* Unity Labs are laser-focused on a **developer-centric learning path**. The goal of these labs is to help you ramp up on Unity quickly, with the same focus on brain-friendly just-in-time learning you'll see throughout *Head First C#* to **give you lots of targeted, effective practice with C# ideas and techniques**.

Download Unity Hub

Unity Hub is an application that helps you manage your Unity projects and your Unity installations, and it's the starting point for creating your new Unity project. Start by downloading Unity Hub from <https://unity.com/developer-tools>—then install it and run it.

All of the screenshots in this book were taken with the free Personal Edition of Unity. You'll need to enter your unity.com username and password into Unity Hub to activate your license.



Click on Installs to manage the installed versions of Unity.

Unity Hub helps you manage your Unity installs and projects. We used screenshots from Unity 6 in these Unity Labs, because that was the most recent version available when we went to production. You should install the latest official release. When you click the Install Editor button, Unity Hub will display a list of official releases. Install the most recent version of Unity 6. Make sure you choose the version (x64 or Arm64) that matches your hardware.

Unity Hub lets you install multiple versions of Unity on the same computer, so you should install the same version that we used to build these labs. **Click the Install Editor button** and install the version of **Unity 6** that matches your hardware (x64 or Arm64—that's the same version we used to take the screenshots in these labs. Once it's installed, make sure that it's set as the preferred version.

The Unity installer may prompt you to install a different version of Visual Studio. You can have multiple installations of Visual Studio on the same computer too, but if you already have one version of Visual Studio installed there's no need to make the Unity installer add another one.

You can learn more about installing Unity Hub on Windows and macOS here:
<https://docs.unity3d.com/Manual/GettingStartedInstallingUnity.html>

Unity Hub lets you have many Unity installs on the same computer. So even if there's a newer version of Unity available, you can use Unity Hub to install the version we used in the Unity Labs.



Watch it!

Unity Hub may look a little different.

The screenshots in this book were taken with **Unity 6** and **Unity Hub 3.10.0**. You can use Unity Hub to install many different versions of Unity on the same computer, but you can only install the latest version of Unity Hub. The Unity development team is constantly improving Unity Hub and the Unity editor, so it's possible that what you see won't quite match what's shown on this page.

Use Unity Hub to create a new project

Click the **New project** button on the Project page in Unity Hub to create a new Unity project. Name it **Unity Lab 1**, select the **Universal 3D** template, and check that you're creating it in a sensible location (usually the Unity Projects folder underneath your home directory).

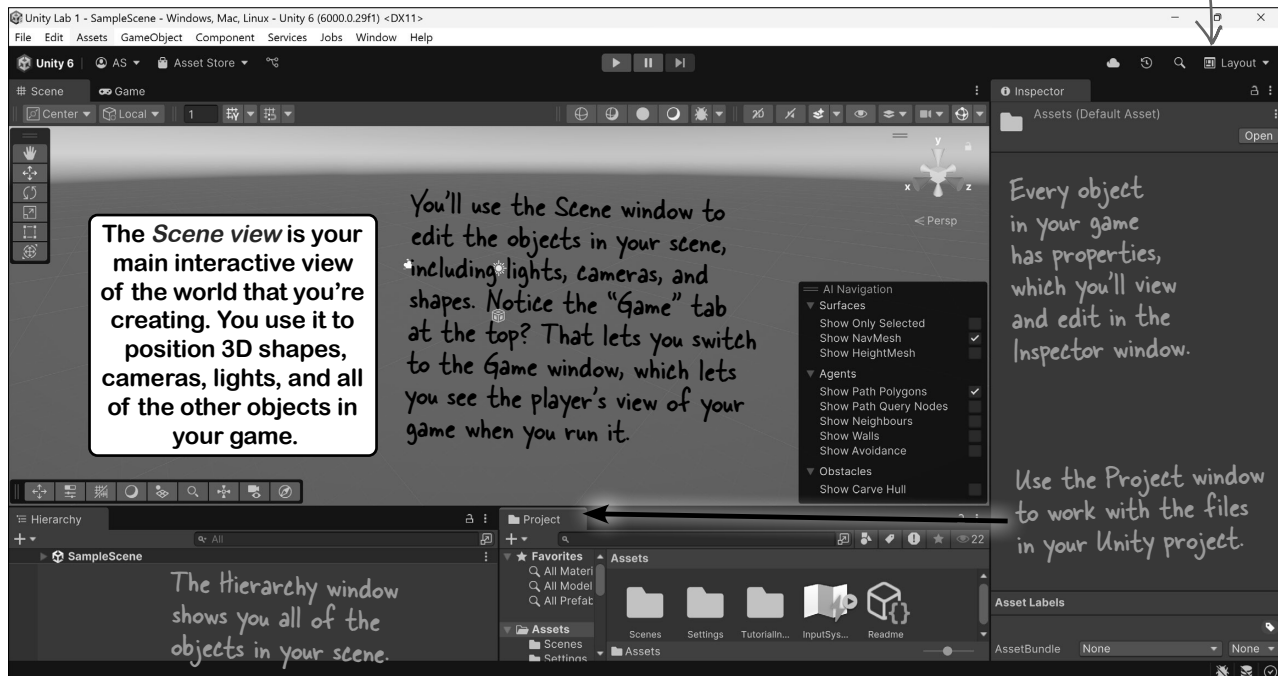


Click Create Project to create the new folder with the Unity project. When you create a new project, Unity generates a lot of files (just like Visual Studio does when it creates new projects for you). It could take Unity a minute or two to create all of the files for your new project.

Work with your project in the Unity editor

Once your project is created, it will load in the **Unity editor**, a powerful tool that you'll use to create 3D environments. Here are some important parts of the Unity editor:

You can use this dropdown to change the layout of the Unity editor.



OK! You're all ready to get started on your first Unity project.

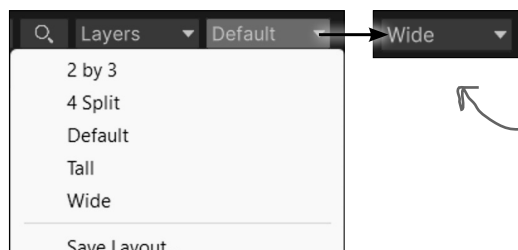
Take control of the Unity layout

The Unity editor is like an IDE for all of the parts of your Unity project that aren't C#. You'll use it to work with scenes, edit 3D shapes, create materials, and so much more.

When you started up Unity, did you notice that your screen looked a little different from our screenshot? Just like in Visual Studio, the windows and panels in the Unity editor can be rearranged in many different layouts. We chose a layout that works well for screenshots in a book. We also chose dark mode, which we think is easier to read when these pages are printed.

Choose the Wide layout to match our screenshots

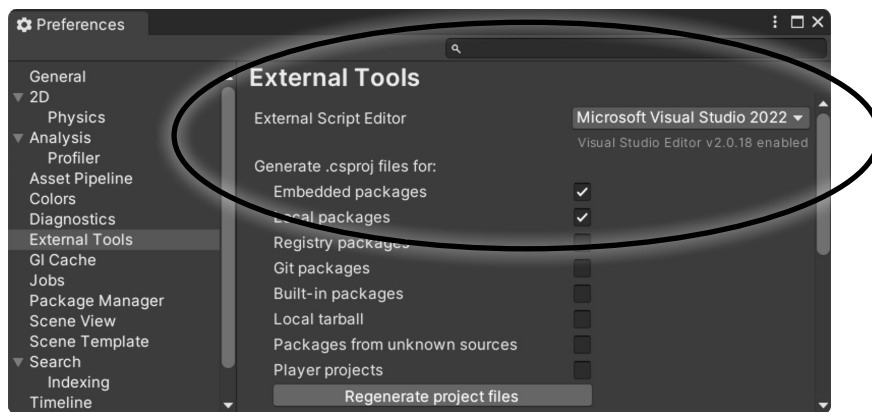
We've chosen the Wide layout because it works well for the screenshots in these labs. Find the Layout dropdown in the toolbar and choose Wide so your Unity editor looks like ours.



Once you change the layout with the Layout dropdown on the right side of the toolbar, the dropdown changes its label to match the layout that you selected.

Set up Unity to work with Visual Studio

The goal of these Unity Labs is to give you an **exciting and fun way to explore C#**. The Unity editor works with Visual Studio and VSCode to make it easy to edit and debug the code for your games. Open the **Unity Preferences Window** (on Windows choose Preferences from the Edit menu; on a Mac choose Settings from the Unity menu). Click on External Tools on the left, click the External Script Editor dropdown, and **choose Visual Studio 2022** (or **Visual Studio Code** if you're using VSCode) from the list of options.



If you don't see Visual Studio in the External Script Editor dropdown, choose *Browse* and navigate to Visual Studio. On Windows it's normally an executable called `devenv.exe` in the folder `C:\Program Files\Microsoft Visual Studio\2022\Community\Common7\IDE\`. On a Mac it's typically an app called Visual Studio in the Applications folder.

You can download PDFs of all of these Unity Labs and print them out if that makes it easier for you to follow along.

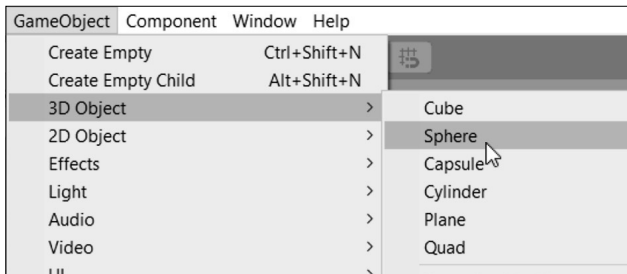
You can use Visual Studio to debug the code in your Unity games. Just choose Visual Studio as the external script editor in Unity's preferences.

↑
You'll write code and do some debugging with Visual Studio or VSCode in the next Unity Lab. This lab is about getting used to the way Unity works so you're ready to do that.

Your scene is a 3D environment

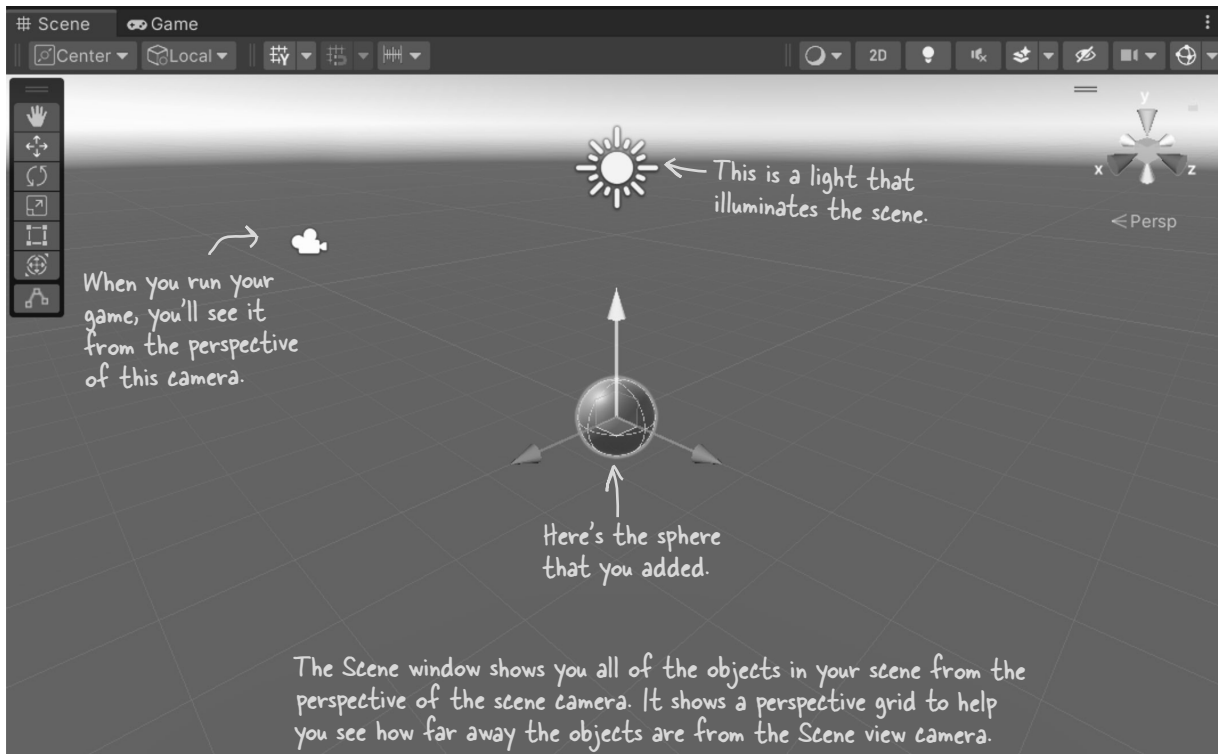
As soon as you start the editor, you're editing a **scene**. You can think of scenes as levels in your Unity games. Every game in Unity is made up of one or more scenes. Each scene contains a separate 3D environment, with its own set of lights, shapes, and other 3D objects. When you created your project, Unity added a scene called `SampleScene` and stored it in a file called `SampleScene.unity`.

Add a sphere to your scene by choosing **GameObject >> 3D Object >> Sphere** from the menu:



These are called Unity's "primitive objects." We'll be using them a lot throughout these Unity Labs.

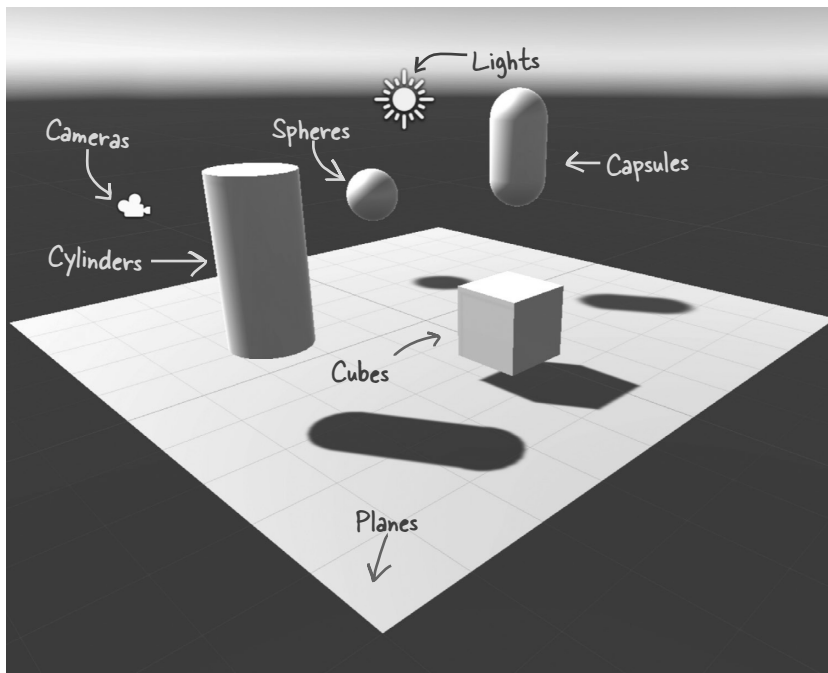
A sphere will appear in your Scene window. Everything you see in the Scene window is shown from the perspective of the **Scene view camera**, which "looks" at the scene and captures what it sees.



Unity games are made with GameObjects

When you added a sphere to your scene, you created a new **GameObject**. The **GameObject** is a fundamental concept in Unity. Every item, shape, character, light, camera, and special effect in your Unity game is a **GameObject**. Any scenery, characters, and props that you use in a game are represented by **GameObjects**.

In these Unity Labs, you'll build games with different kinds of **GameObjects**, including:



Each **GameObject** contains several **components** that provide its shape, set its position, and give it all of its behavior. For example:

- ★ *Transform components* determine the position and rotation of the **GameObject**.
- ★ *Material components* change the way the **GameObject** is **rendered**—or how it's drawn by Unity—by changing the color, reflection, smoothness, and more.
- ★ *Script components* use C# scripts to determine the **GameObject**'s behavior.

ren-der, verb.

to represent or depict artistically.

*Michelangelo **rendered** his favorite model with more detail than he used in any of his other drawings.*

GameObjects are the fundamental objects in Unity, and components are the basic building blocks of their behavior. The Inspector window shows you details about each **GameObject** in your scene and its components.

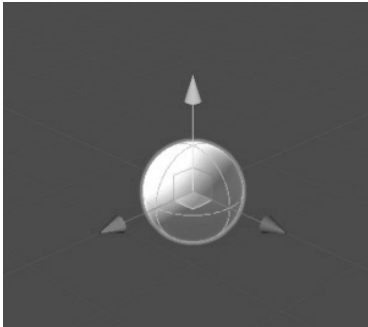
Use the Move Gizmo to move your GameObjects

The Tools panel lets you choose **Transform tools**. If the Move Tool isn't selected, click on the sphere that you just added, then click the Move Tool in the **Tools overlay** to select it.



The *Tools overlay* lets you choose tools to manipulate GameObjects. You'll use the *Move Tool* to move your sphere around the scene. In the *Wide view*, the *Tools overlay* is vertical. You can right-click the two lines at the top to change its orientation so it's horizontal, or you can drag it to the toolbar or the side of the window to dock it.

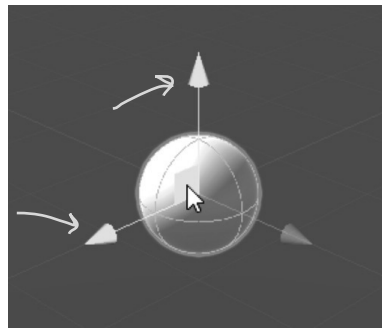
The **Move Tool** lets you use the **Move Gizmo** to move GameObjects around the 3D space. You should see red, green, and blue arrows and a cube appear in the middle of the window. This is the Move Gizmo, which you can use to move the selected object around the scene.



Using the Move Tool displays the Move Gizmo as arrows and a cube on top of the GameObject that's currently selected. When you click the sphere and then choose the Move Tool, you'll see the Move Gizmo appear on the sphere. Click anywhere else in the scene to deselect the sphere and the Move Gizmo goes away.

Move your mouse cursor over the cube at the center of the Move Gizmo—notice how each of the faces of the cube lights up as you move your mouse cursor over it? Click on the *upper-left face* and drag the sphere around. You're moving the sphere in the X-Y plane.

When you click on the upper-left face of the cube in the middle of the Move Gizmo, its X and Y arrows light up and you can drag your sphere around the X-Y plane in your scene.



The Move Gizmo lets you move GameObjects along any axis or plane of the 3D space in your scene.

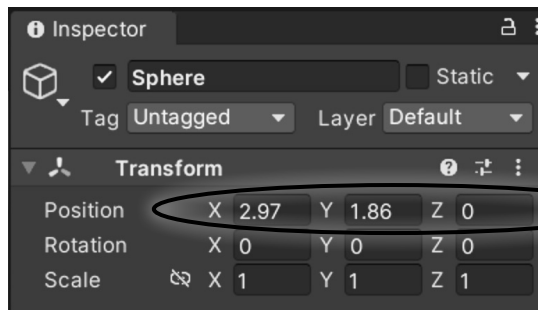
Move your sphere around the scene to get a feel for how the Move Gizmo works. Click and drag each of the three arrows to drag it along each plane individually. Try clicking on each of the faces of the cube in the Scene Gizmo to drag it around all three planes. Notice how the sphere gets smaller as it moves farther away from you—or really, the scene camera—and larger as it gets closer.

The Inspector shows your GameObject's components

As you move your sphere around the 3D space, watch the **Inspector window**, which is on the right side of the Unity editor if you're using the Wide layout. Look through the Inspector window—you'll see that your sphere has four components labeled Transform, Sphere (Mesh Filter), Mesh Renderer, and Sphere Collider.

Every GameObject has a set of components that provide the basic building blocks of its behavior, and every GameObject has a **Transform component** that drives its location, rotation, and scale.

You can see the Transform component in action as you use the Move Gizmo to drag the sphere around the X-Y plane. Watch the X and Y numbers in the Position row of the Transform component change as the sphere moves.

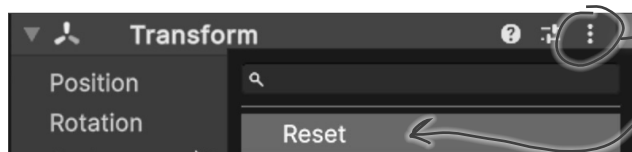


Did you notice the grid in your 3D space? As you're dragging the sphere around, *hold down the Control key*. That causes the GameObject that you're moving to snap to the grid. You'll see the numbers in the Transform component move by whole numbers instead of small decimal increments.

Try clicking on each of the other two faces of the Move Gizmo cube and dragging to move the sphere in the X-Z and Y-Z planes. Then click on the red, green, and blue arrows and drag the sphere along just the X, Y, or Z axis. You'll see the X, Y, and Z values in the Transform component change as you move the sphere.

Now **hold down Shift** to turn the cube in the middle of the Gizmo into a square. Click and drag on that square to move the sphere in the plane that's parallel to the Scene view camera.

Once you're done experimenting with the Move Gizmo, use the sphere's Transform component context menu to reset the component to its default values. Click the **context menu button** (☰) at the top of the Transform panel and choose Reset from the menu.



Use the context menu to reset a component. You can either click the three dots or right-click anywhere in the top line of the Transform panel in the Inspector window to bring up the context menu.

The position will reset back to [0, 0, 0].

You can learn more about the tools and how to use them to position GameObjects in the Unity Manual. Click [Help >> Unity Manual](#) and search for the "Positioning GameObjects" page.

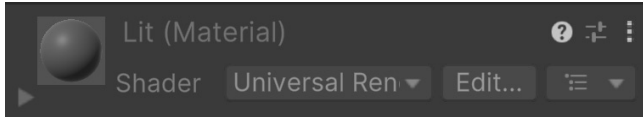
Save your scene often! Use File >> Save or Ctrl+S / ⌘S to save the scene right now.

Add a material to your Sphere GameObject

Unity uses **materials** to provide color, patterns, textures, and other visual effects. Your sphere looks pretty boring right now because it just has the default material, which causes the 3D object to be rendered in a plain, off-white color. Let's make it look like a billiard ball.

① Select the sphere.

When the sphere is selected, you can see its material as a component in the Inspector window:



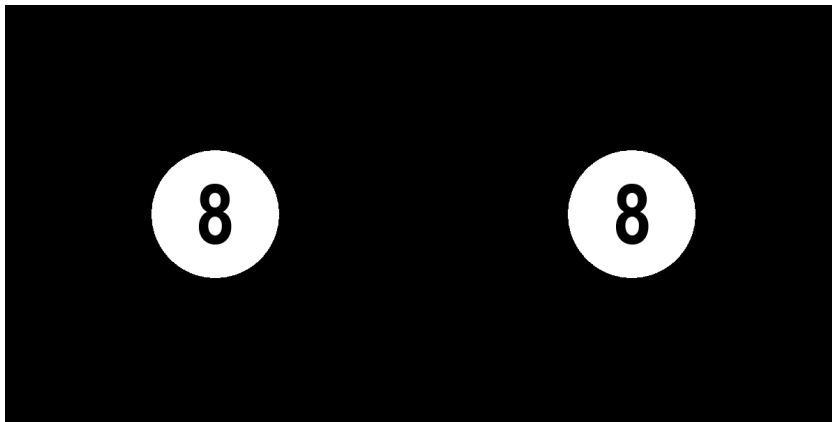
We'll make your sphere more interesting by adding a **texture**—that's just a simple image file that's wrapped around a 3D shape, almost like you printed the picture on a rubber sheet and stretched it around your object.

② Go to our Billiard Ball Textures page on GitHub.

Go to <https://github.com/head-first-csharp/fifth-edition> and click on the *Billiard Ball Textures* link to browse a folder of texture files for a complete set of billiard balls.

③ Download the texture for the 8 ball.

Click on the file *8 Ball Texture.png* to view the texture for an 8 ball. It's an ordinary 1200 × 600 PNG image file that you can open in your favorite image viewer.



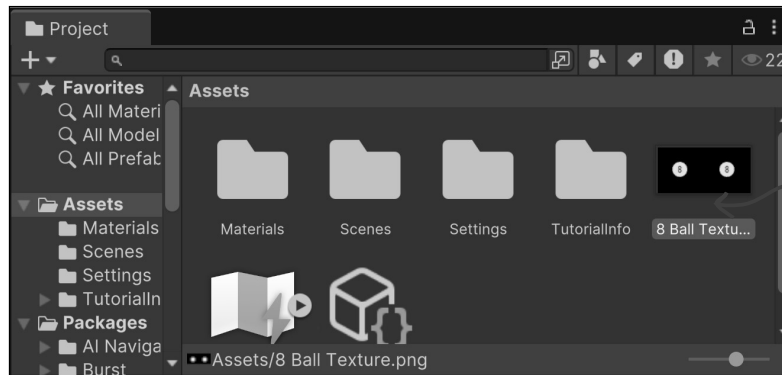
← We designed this image file so that it looks like an 8 ball when Unity "wraps" it around a sphere.

Download the file into a folder on your computer.

(You might need to right-click on the Download button to save the file, or click Download to open it and then save it, depending on your browser.)

④ Import the 8 Ball Texture image into your Unity project.

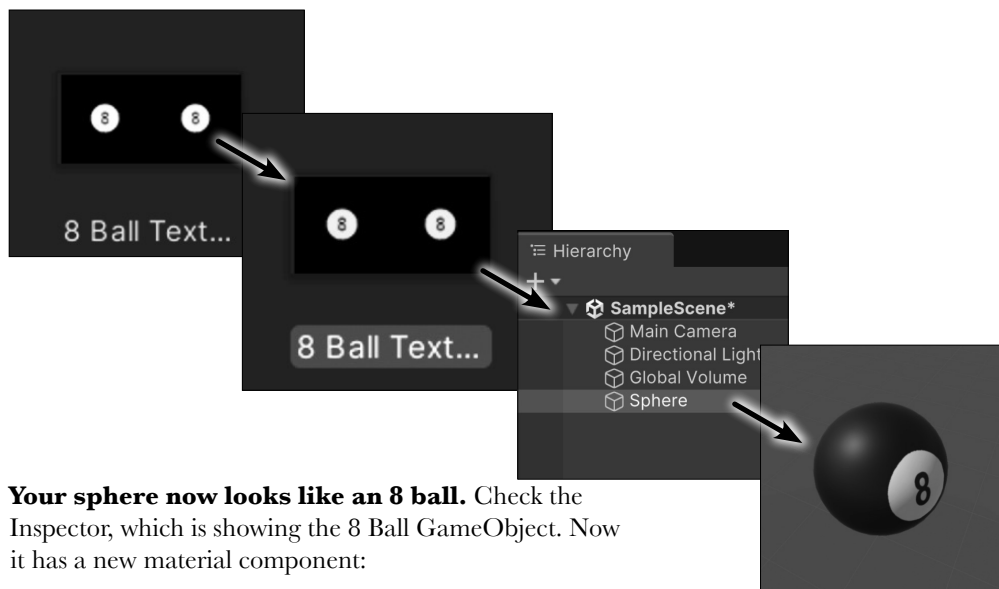
Right-click on the Assets folder in the Project window, choose **Import New Asset** and import the texture file. You should now see it when you click on the Assets folder in the Project window.



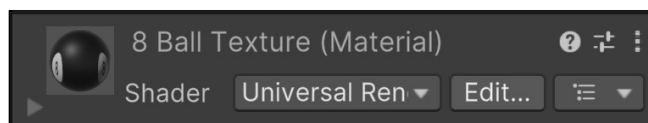
You right-clicked inside the Assets folder in the Project window to import the new asset, so Unity imported the texture into that folder.

⑤ Add the texture to your sphere.

Now you just need to take that texture and “wrap” it around your sphere. Click on 8 Ball Texture in the Project window to select it. Once it’s selected, **drag it into the Hierarchy window onto the Sphere that you added.**



Your sphere now looks like an 8 ball. Check the Inspector, which is showing the 8 Ball GameObject. Now it has a new material component:



Check your Assets window again. Unity created a new Materials folder in it and added a material called 8 Ball Texture.



I'm learning C# for my job, not to write video games. Why should I care about Unity?

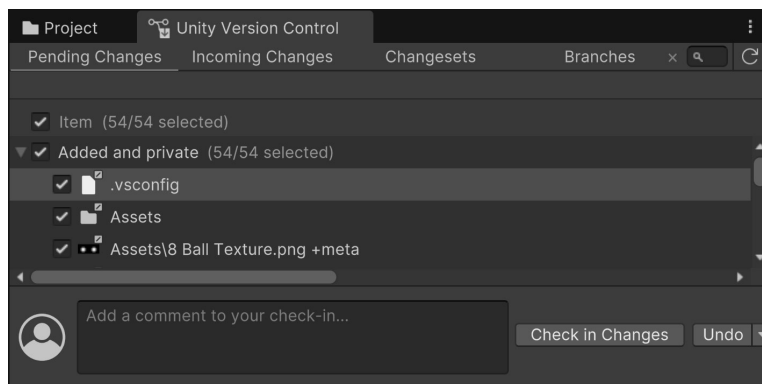
Unity is a great way to really “get” C#.


Programming is a skill, and the more practice you get writing C# code, the better your coding skills will get. That’s why we designed the Unity Labs throughout this book to specifically **help you practice your C# skills** and reinforce the C# tools and concepts that you learn in each chapter. As you write more C# code, you’ll get better at it, and that’s a really effective way to become a great C# developer. Neuroscience tells us that we learn more effectively when we experiment, so we designed these Unity Labs with lots of options for experimentation, and suggestions for how you can get creative and keep going with each lab.

But Unity gives us an even more important opportunity to help get important C# concepts and techniques into your brain. When you’re learning a new programming language, it’s really helpful to see how that language works with lots of different platforms and technologies. That’s why we included both console apps and MAUI apps in the main chapter material, and in some cases even have you build the same project using both technologies. Adding Unity to the mix gives you a third perspective, which can accelerate your understanding of C#.

Do you want to make sure your Unity projects are always backed up? Try Unity Version Control.

Unity Version Control is a version control system that lets you back up your projects to cloud storage that comes free with your Unity account—and it’s **built right into the Unity editor**, which makes it easy for you to use.

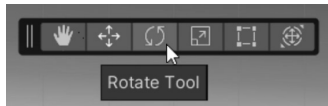


Click the  Unity Version Control button in the toolbar to open the Unity Version Control window. The first time you use it, you’ll get an option to log in or sign up. When you sign in with your Unity ID, you’ll get to a web page where you can sign into your Unity account, then sign up for the free Unity VCS level and join your default organization. Then you can check in changes any time you want.

Go to the Head First C# GitHub page for a free PDF that gives you step-by-step instructions for setting Unity Version Control: <https://github.com/head-first-csharp/fifth-edition>

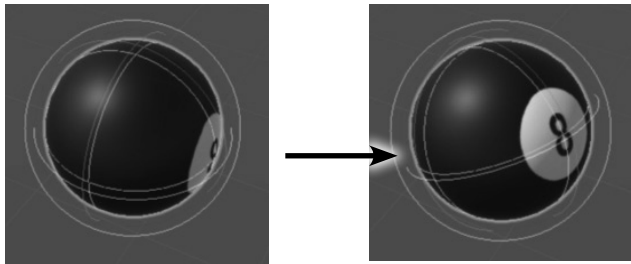
Rotate your sphere

Click the **Rotate tool** in the toolbar. You can use the Q, W, E, R, T, and Y keys to quickly switch between the Transform tools—press E and W to toggle between the Rotate tool and Move Tool.

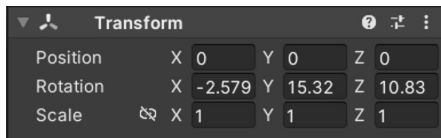


We switched the Tools overlay to a horizontal view by right-clicking on the two lines and choosing Horizontal. Try it out.

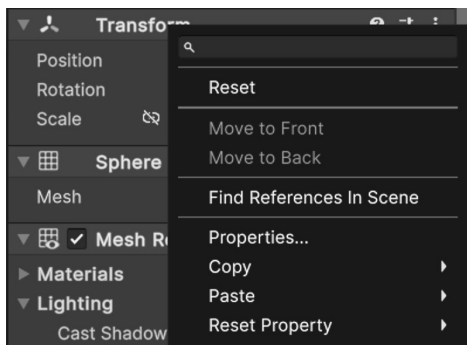
- 1 **Click on the sphere.** Unity will display a wireframe sphere Rotate Gizmo with red, blue, and green circles. Click the red circle and drag it to rotate the sphere around the X axis.



- 2 **Click and drag the green and blue circles to rotate around the Y and Z axes.** The outer white circle rotates the sphere along the axis coming out of the Scene view camera. Watch the Rotation numbers change in the Inspector window.



- 3 **Open the context menu of the Transform panel in the Inspector window.** Click Reset, just like you did before. It will reset everything in the Transform component back to default values—in this case, it will change your sphere's rotation back to [0, 0, 0].



Click the three dots (or right-click anywhere in the header of the Transform panel) to bring up the context menu. The Reset option at the top of the menu resets the component to its default values.

Use these options from farther down in the context menu to reset the position and rotation of a GameObject.

Relax

It's easy to reset your windows and scene camera.

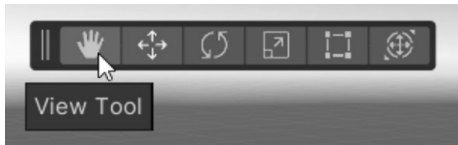
If you change your Scene view so you can't see your sphere anymore, or if you drag your windows out of position, just use the Layout dropdown in the upper-right corner to reset the Unity editor to the Wide layout. It will reset the window layout and the Scene view

Use File >> Save or Ctrl+S / ⌘S to save the scene right now. Save early, save often!

Move the Scene view camera with the View Tool and Scene Gizmo

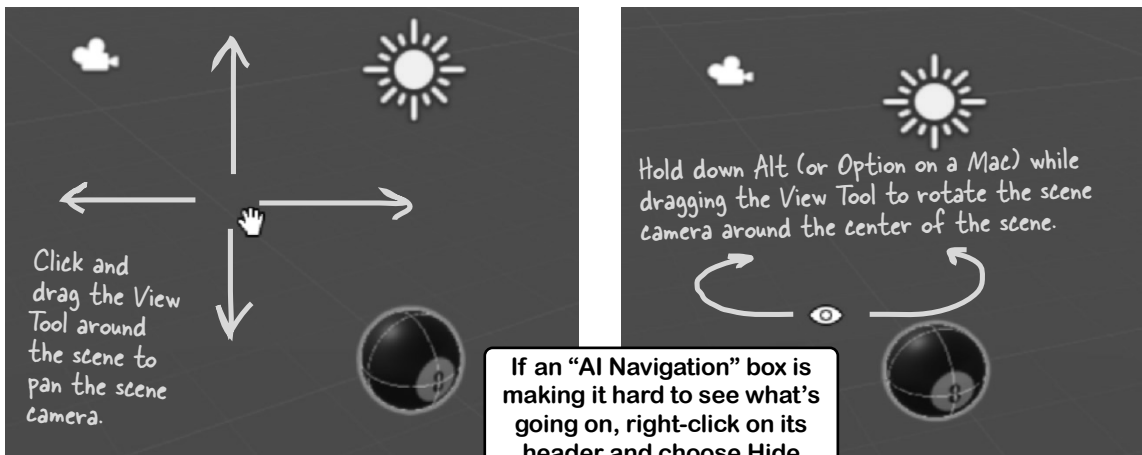
Use the mouse scroll wheel or scroll feature on your trackpad to zoom in and out, and toggle between the Move and Rotate Gizmos. Notice that the sphere changes size, but the Gizmos don't. The Scene window in the editor shows you the view from a virtual **camera**, and the scroll feature zooms that camera in and out.

Press **Q** to select the **View Tool**, or choose it from the toolbar. Your cursor will change to a hand.



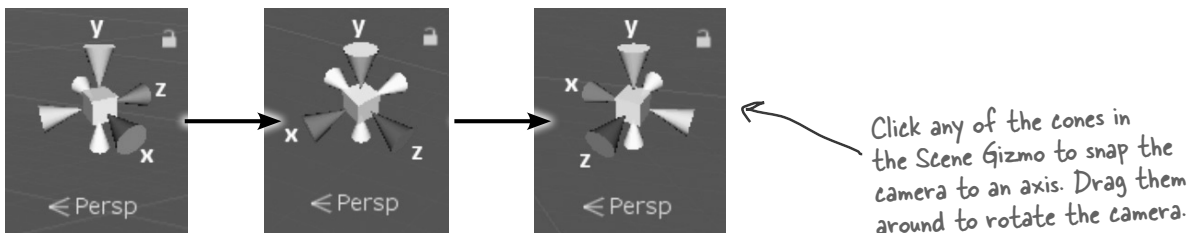
Hold down **ALT** (Windows) or **Option** (Mac) while dragging and the View Tool turns into an eye and rotates the view around the center of the window.

The View Tool pans around the scene by changing the position and rotation of the scene camera. When the View Tool is selected, you can click anywhere in the scene to pan.



When the View Tool is selected, you can **pan** the scene camera by **clicking and dragging**, and you can **rotate** it by **holding down ALT (or Option) and dragging**. Use the **mouse scroll wheel** to zoom. Holding down the **right mouse button** lets you **fly through the scene** using the W-A-S-D keys.

When you rotate the scene camera, keep an eye on the **Scene Gizmo** in the upper-right corner of the Scene window. The Scene Gizmo always displays the camera's orientation—check it out as you use the View Tool to move the Scene view camera. Click on the X, Y, and Z cones to snap the camera to an axis. Drag them around to rotate the camera.



The Unity Manual has great tips on navigating scenes: <https://docs.unity3d.com/Manual/SceneView.Navigation.html>

Take a minute and look at this page—it's got some really useful stuff.

there are no
Dumb Questions

Q: I'm still not clear on exactly what a component is. What does it do, and how is it different from a GameObject?

A: A GameObject doesn't actually do much on its own. All a GameObject really does is serve as a *container* for components. When you used the GameObject menu to add a sphere to your scene, Unity created a new GameObject and added all of the components that make up a sphere, including a Transform component to give it position, rotation, and scale, a default material to give it its plain white color, and a few other components to give it its shape, and help your game figure out when it bumps into other objects. These components are what make it a sphere.

Q: So does that mean I can just add any component to a GameObject and it gets that behavior?

A: Yes, exactly. When Unity created your scene, it added two GameObjects, one called Main Camera and another called Directional Light. If you click on Main Camera in the Hierarchy window, you'll see that it has three components: a Transform, a Camera, and an Audio Listener. If you think about it, that's all a camera actually needs to do: be somewhere, and pick up visuals and audio. The Directional Light GameObject just has two components: a Transform and a Light, which casts light on other GameObjects in the scene.

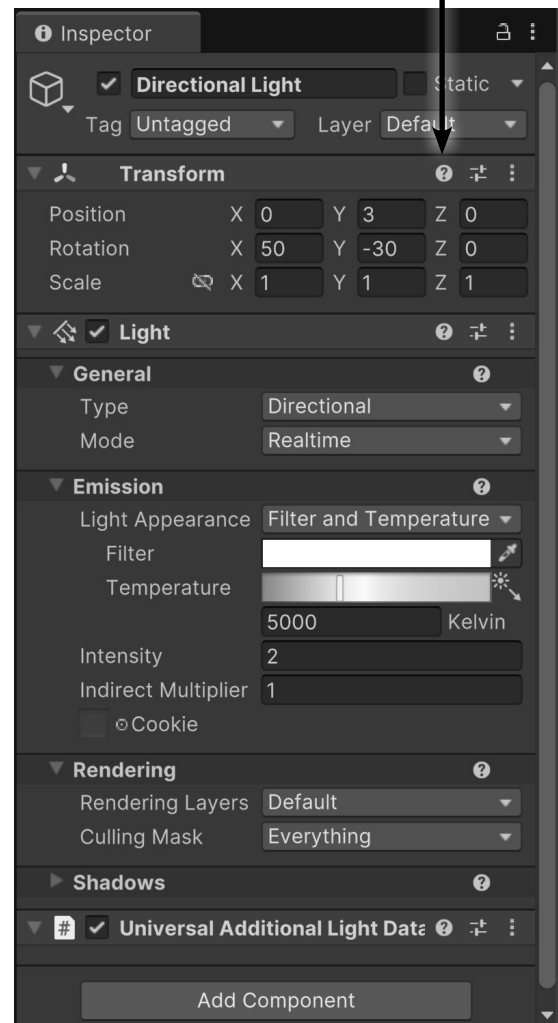
Q: If I add a Light component to any GameObject, does it become a light?

A: Yes! A light is just a GameObject with a Light component. If you click on the Add Component button at the bottom of the Inspector and add a Light component to your ball, it will start emitting light. If you add another GameObject to the scene, it will reflect that light.

Q: It sounds like you're being careful with the way you talk about light. Is there a reason you talk about emitting and reflecting light? Why don't you just say that it glows?

A: Because there's a difference between a GameObject that emits light and one that glows. If you add a Light component to your ball, it will start emitting light—but it won't look any different, because the Light only affects other GameObjects in the scene that reflect its light. If you want your GameObject to glow, you'll need to change its material or use another component that affects how it's rendered.

You can click on the Help icon for any component to bring up the Unity Manual page for it.



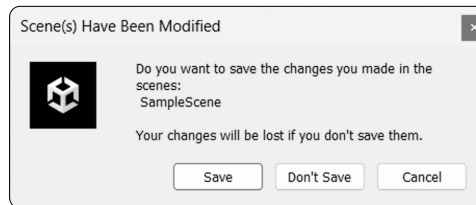
When you click on the Directional Light GameObject in the Hierarchy window, the Inspector shows you its components. It just has two: a Transform component that provides its position and rotation and a Light component that actually casts the light. What do you think you'll use the Add Component button for?

Get creative!

We built these Unity Labs to give you a **platform to experiment on your own with C#** because that's the single most effective way for you to become a great C# developer. This lab **lays down the foundation** to start writing Unity code—which you'll do in the next lab. At the end of each Unity Lab, we'll include suggestions for things that you can try on your own. Take some time to experiment with everything you just learned before moving to the next chapter:

- ★ Add a few more spheres to your scene. Try using some of the other billiard ball maps. You can download them all from the same location where you downloaded *8 Ball Texture.png*.
- ★ Try adding other shapes by choosing Cube, Cylinder, or Capsule from the GameObject >> 3D Object menu.
- ★ Experiment with using different images as textures. See what happens to photos of people or scenery when you use them to create textures and add them to different shapes.
- ★ Can you create an interesting 3D scene out of shapes, textures, and lights?

When you're ready to move on to the next chapter, make sure you save your project, because you'll come back to it in the next lab. Unity will prompt you to save when you quit.



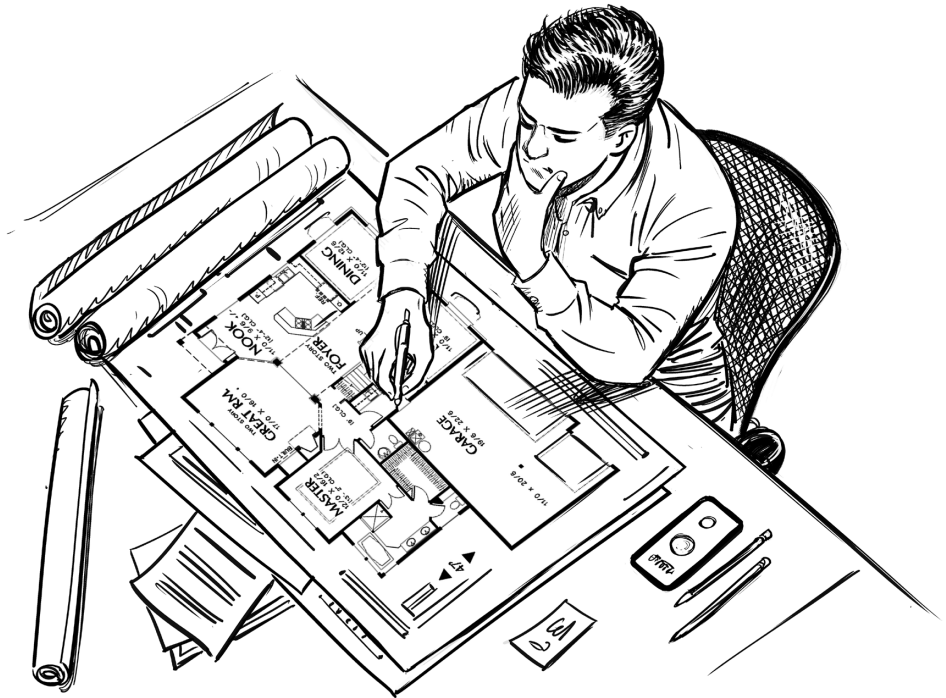
The more C# code you write, the better you'll get at it. That's the most effective way for you to become a great C# developer. We designed these Unity Labs to give you a platform for practice and experimentation.

Bullet Points

- The **Scene view** is your main interactive view of the world that you're creating.
- When you select an object and use the **Move Tool**, Unity displays the **Move Gizmo** that lets you move objects around your scene.
- The **View Tool** lets you pan around the scene. The **Scene Gizmo** always displays the camera's orientation.
- Unity uses **materials** to provide color, patterns, textures, and other visual effects.
- Some materials use **textures**, or image files wrapped around shapes.
- Your game's scenery, characters, props, cameras, and lights are all built from **GameObjects**.
- GameObjects are the fundamental objects in Unity. **Components** are the building blocks for their behavior.
- Every GameObject has a **Transform component** that provides its position, rotation, and scale.
- The **Project window** gives you a folder-based view of your project's assets, including C# scripts and textures.
- The **Hierarchy window** shows all of the GameObjects in the scene.
- **Unity Version Control System (VCS)** is an easy way to back up projects to free cloud storage that comes with a Unity Personal account. Download a PDF to help you set up version control in Visual Studio, VSCo, and Unity for free from our GitHub page: <https://github.com/head-first-csharp/fifth-edition>

3 namespaces and classes

Organizing your code



Great developers keep their code and data organized.

What's the first thing you do when you're creating an app? You think about what **it's supposed to do**, whether you're solving a problem, creating a game, or just having fun. But it's not always obvious how individual statements fit into your app's bigger picture...and that's where **classes** come in. They let you **organize your code** around the features you're creating and the problems the app needs to solve. Classes can help you **organize your data**, too, by using them to create **objects** that represent any "thing" your app needs to know about—and the classes that you design serve as "blueprints" for the objects used in your app.

Classes help you organize your code

Let's be honest...you're going to write a lot of code throughout this book. And as you keep going through the chapters, your projects will get bigger and bigger. This is a good thing!

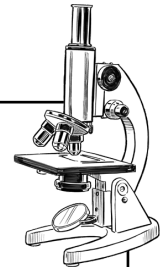
Bigger apps present an interesting challenge. The app you built at the end of Chapter 2 had just a few methods. If you create a console app with the same number of methods, there's no reason not to put them all in *Program.cs*.

By the time you get to the end of the book, you'll be creating apps with *dozens* of methods. If you put all of those methods into one big *Program.cs* file, you'll have a hard time remembering which ones do what—and you'll drive yourself crazy trying to sleuth out bugs!

Luckily, C# has an answer for this organizational challenge. Your C# code is organized into **classes**, or units of code that contain methods. You could still put all of your methods into one big class, and many small apps could have just one class. But when you have a lot of code, it makes sense to **organize your classes based on what they do**. When your classes are organized in a way that's intuitive, it helps you figure out where to add new methods—and it makes sleuthing out bugs a lot easier.



Anatomy of a C# App



Every C# program's code is structured in exactly the same way. All programs use *namespaces*, *classes*, and *methods* to make your code easier to manage.

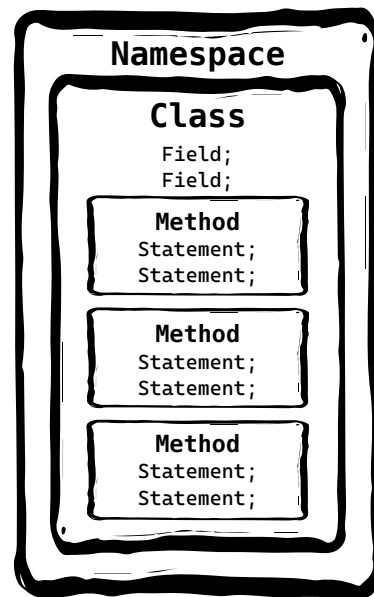
When you create your app, all of the code is inside a *namespace*. This helps keep your classes separate from the ones that come with .NET.

A *class* contains a piece of your program. Some very small programs can have just one class, but most have more.

A class can have *fields*. A field is a variable, except that it's declared outside of the methods so all of the methods in the class can use it.

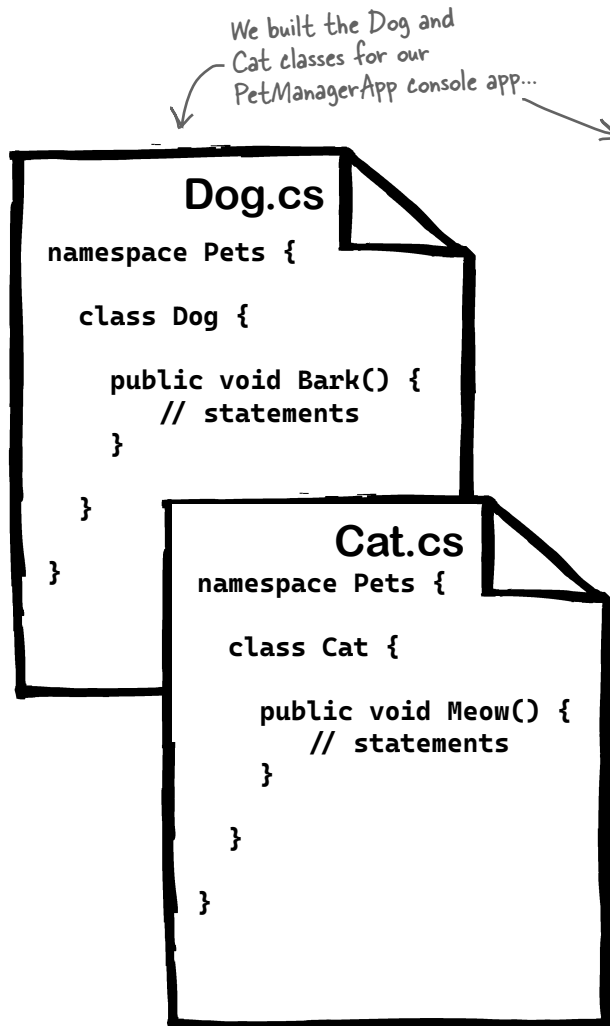
A class has one or more *methods*. Your methods must live inside a class. The order of the methods in the class file doesn't matter. Method 2 can just as easily come before method 1.

Methods are made up of *statements*—like the ones you used in your apps in the last two chapters.

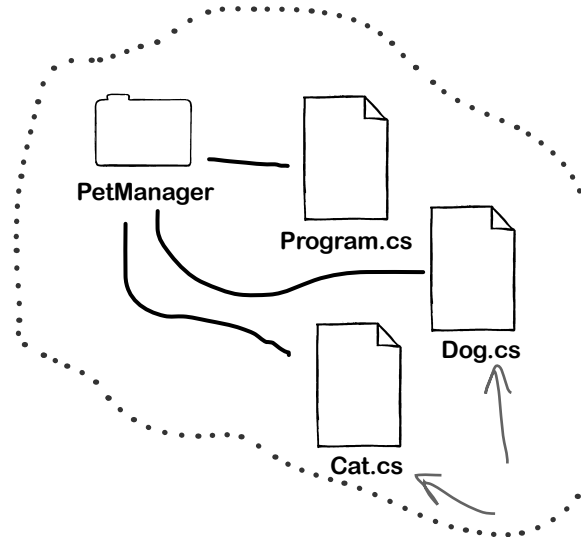


If code is useful, classes can help you reuse it

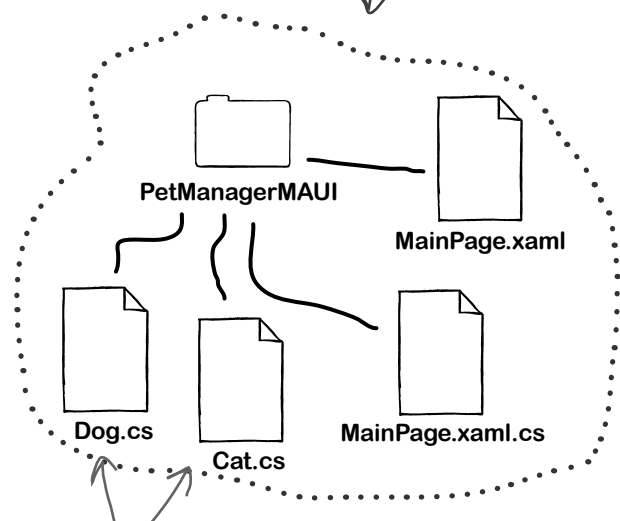
Developers have been reusing code since the earliest days of programming, and it's not hard to see why. If you've written a class for one program, and you have another program that needs code that does exactly the same thing, then it makes sense to **reuse** the same class in your new program. So if we were going to build an app called PetManager, we might organize the code using classes called Dog and Cat.



Since we put our classes in the Pets namespace, we just had to copy the file into the new project and add "using Pets;" to the top of any file with C# code that uses the Dog or Cat classes.



...but we discovered we needed exactly the same classes in the MAUI version of our PetManager app, so we reused them.



These are the same files with the Dog and Cat classes.

Some methods take parameters and return a value

You've seen methods that do things, like the `OperatorExamples` method you generated in Chapter 2. Methods can do more than that: they can use **parameters** to get input, do something with that input, and then generate output with a **return value** that can be used by the statement that called the method.



Parameters are values that the method uses as input. They're declared as variables that are included in the method declaration (between the parentheses). The return value is a value that's calculated or generated inside the method, and sent back to the statement that called that method. The type of the return value (like *string* or *int*) is called the **return type**. If a method has a return type, then it must use a **return statement**.

Here's an example of a method with two `int` parameters and an `int` return type:

```
int Multiply(int factor1, int factor2)
{
    int product = factor1 * factor2;
    return product;
}
```

The return type is `int`, so the method must return an `int` value.

This method takes two `int` parameters called `factor1` and `factor2` as input. They're treated just like `int` variables.

The return statement passes the value back to the statement that called the method.

The method takes two **parameters** called `factor1` and `factor2`. It uses the multiplication operator `*` to calculate the result, which it returns using the **return** keyword.

This code calls the `Multiply` method and stores the result in a variable called `area`:

```
int height = 179;
int width = 83;
int area = Multiply(height, width);
```

You can pass values like 3 and 5 to methods, like this: `Multiply(3, 5)`—but you can also use variables when you call your methods. It's fine if the variable names don't match the parameter names.

A method's parameters let you give it information that it can use, and its return value lets you use the result of the method in the statement that called it.

Visual Studio helps you explore parameters and return values

In the next app, you'll be using a .NET method called **Console.ReadLine** to get a line that the user types into the console. Once you add the line to your app, you can hover over it to see more about it:

```
Console.ReadLine();
```

This method returns a `string?` value that holds a line of text that the user typed.

```
string? Console.ReadLine()
Reads the next line of characters from the standard input stream.

Returns:
  The next line of characters from the input stream, or null if no more lines are available.

Exceptions:
  IOException
  OutOfMemoryException
  ArgumentOutOfRangeException
```

This pop-up is called the *Quick Info window*, and it's a really useful part of Visual Studio's IntelliSense system. Read it really carefully. We'll use this window throughout the book as a learning tool. (VSCode has a similar pop-up.)

The IDE will pop up a box telling you what the method does. The very first thing in the box is its return type—in this case, it's a **string?** value that holds text. We'll learn a lot more about how strings work in the next chapter. In the meantime, what you need to know is that you call the method like this:

```
string? line = Console.ReadLine();
```

This calls the method to read a line of input, and stores the text the user typed in a variable called **line**.

You'll also use a method called `int.TryParse()`, which you'll use in an **if** statement like this:

```
if (int.TryParse(line, out int numberOfCards))
```

```
bool int.TryParse(string? s, out int result) (+ 8 overloads)
Converts the string representation of a number to its 32-bit signed integer equivalent. A return value indicates whether the conversion succeeded.

Returns:
  true if s was converted successfully; otherwise, false.
```

This method takes two parameters, a `string?` that contains text to turn into a number, and a result that the value gets saved into.

The IDE is telling you that it takes two parameters, a **string?** value and an **out int** value. (We'll learn a lot more about the **out** keywords later in the book—for now, we'll give you the code to use.)

Do this! →

Since you're about to create methods that return values, right now is a perfect time to write some code and use the debugger to *really dig into how the return statement works*:

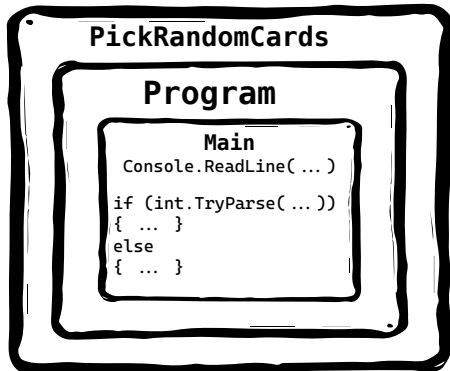
- ★ What happens when a method is done executing all of its statements? See for yourself—open up one of the programs you've written so far, place a breakpoint inside a method, then keep stepping through it.
- ★ When the method runs out of statements, it **returns** to the statement that called it and continues executing the next statement after that.
- ★ A method can also include a **return** statement, which causes it to immediately exit without executing any of its other statements. Try adding a **return** statement in the middle of a method, then stepping over it.

Let's build an app that picks random cards

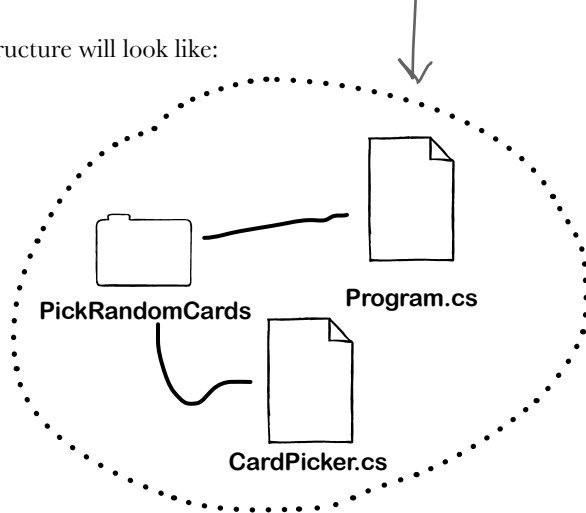
In the first project in this chapter, you're going to build a console app called PickRandomCards that lets you pick random playing cards.

Let's use it as a way to **start using classes**. Here's what its structure will look like:

You're going to create a console app that has a *Main* method instead of top-level statements (which we'll talk more about). Your *Program.cs* file will contain a class. That class will have a method called *Main*, which is the first thing that gets run when you start the app.

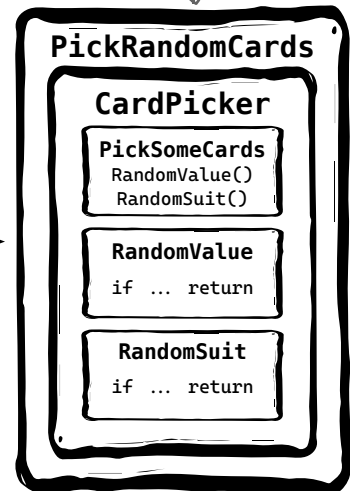


Your PickRandomCards app will have a second C# class file called CardPicker.cs, which contains the code for the CardPicker class.



When you create your app you'll call it PickRandomCards, so Visual Studio will create a namespace for you that matches the name of the app.

Your *Main* method will have all the code that communicates with the user, displaying text and getting input. The code that has to do with picking random cards will be in a class called *CardPicker*.



The CardPicker class doesn't have any fields, and that's OK! We'll talk more about fields later in the chapter.

You'll use an array to store the cards

Your `PickSomeCards` method will use string values to represent playing cards. Let's say you want to use your `CardPicker` class to pick five random cards and store them in a variable called `cards`. Here's how you would do that:

```
string[] cards = CardPicker.PickSomeCards(5);
```

There's a lot going on in that line of code, so let's break it down. The `PickSomeCards` method is in the `CardPicker` class, but we're calling it from a top-level statement, so we need to use the class name to call it:

```
string[] cards = CardPicker.PickSomeCards(5);
```

We just learned about how methods can take parameters. The `PickSomeCards` method takes an `int` parameter, and we're passing the method the value `5` to tell it to pick five cards:

```
string[] cards = CardPicker.PickSomeCards(5);
```

The first part of the statement declares the `cards` variable. We just learned about return values—so the method will return a value that gets stored in the `cards` variable. But something looks different about it:

```
string[] cards = CardPicker.PickSomeCards(5);
```

The `cards` variable has a type that you haven't seen yet. Look closely at the type:

```
string[] cards = CardPicker.PickSomeCards(5);
```

The square brackets `[]` mean that it's an **array of strings**. Arrays let you use a single variable to store multiple values—in this case, strings with playing cards—which will get stored in the `cards` variable.

You can use a **collection expression** to create an array of values by putting comma-separated values between two square brackets `[]`. Here's an example of a string array that the `PickSomeCards` method might return:

```
[
    "10 of Diamonds",
    "6 of Clubs",
    "7 of Spades",
    "Ace of Diamonds",
    "Ace of Hearts",
]
```

← This array of strings has five values in it. Each value is a separate string that has the name of a card.

After your array is generated, you can use a **foreach** loop to write each of the cards to the console:

```
foreach (string card in cards) {
    Console.WriteLine(card);
}
```

For the previous array, running that **foreach** loop will generate this output:

```
10 of Diamonds
6 of Clubs
7 of Spades
Ace of Diamonds
Ace of Hearts
```



Create an app with a Main method

When you created console apps in the first two chapters, the IDE generated a two-line *Program.cs* file:

```
// See https://aka.ms/new-console-template for more information
Console.WriteLine("Hello, World!");
```

You may not have realized it at the time, but you were taking advantage of a very useful feature of C# called **top-level statements** that lets you start creating a console app with a simple file that contains a set of statements that get executed in order.

Top-level statements are really convenient! A good way to understand what they do for you and how they work is to **create a C# app that doesn't use top-level statements**.

Do this!

Create your PickRandomCards app without top-level statements

Use Visual Studio to **create a new console app called PickRandomCards**. But unlike previous chapters, when you're going through the steps to create the app, keep an eye out for a checkbox like this and make sure that it's checked:



Make sure you check the "Do not use top-level statements box" when you create your app; otherwise, your *Program.cs* file won't have a *Program* class with *Main* method.

When you create your new app, your *Program.cs* file should look like this:

```
namespace PickRandomCards
{
    internal class Program
    {
        static void Main(string[] args)
        {
            Console.WriteLine("Hello, World!");
        }
    }
}
```

The very first statement that gets executed in an app is called its *entry point*. The entry point in an app with top-level statements is the first statement in *Program.cs*. In an app without top-level statements, the entry point is the *Main* method.

When the IDE created your app and generated the *Program.cs* file, **it added a class called Program**. This program was generated with one method called *Main*. The code inside the *Main* method is the familiar statement that prints "Hello, World!" to the console.

Run your app—it should look very familiar. Your new app does exactly the same thing as the "Hello, World!" app you created in Chapter 1. But instead of starting at the first statement in the *Program.cs* file, the first thing your app does is execute the *Main* method.

Your app can only have one entry point. If you add another class with a *Main* method, your code won't build.



Watch it!

Visual Studio remembers your checkbox choices.

The next time you create a Console App project in Visual Studio, it may remember that you checked the "Do not use top-level statements" box and check it again for you. Make sure it's unchecked the next time you create a console app.

Top-Level Statements

Here's what happens when you use *top-level statements*

Behind the
Scenes



Here's the very first app that you created in Chapter 1:

```
// See https://aka.ms/new-console-template for more information
Console.WriteLine("Hello, World!");
```

The first line is a comment, so there's actually only one statement in this app. When you build the app, the *compiler*—the part of Visual Studio that turns your C# code into something that your operating system can execute—reads all of the lines in the top-level statement and adds them to a class. It creates a class that looks like the one that you just saw in your PickRandomCards app:

```
internal class Program
{
    static void Main(string[] args)
    {
        Console.WriteLine("Hello, World!");
    }
}
```

The top-level statements in this app are in the *global namespace*, a default namespace that contains any classes that aren't explicitly put into a namespace. You can put any class into the global namespace by leaving the namespace declaration off.

That looks a lot like the Program class that Visual Studio just created in your PickRandomCards app. But there's one difference—can you spot it?

Here's the Program class from your PickRandomCards app without top-level statements—we've made text that's the same a lighter color so you can see the difference:

```
namespace PickRandomCards
{
    internal class Program
    {
        static void Main(string[] args)
        {
            Console.WriteLine("Hello, World!");
        }
    }
}
```

If you're using VSCode and don't have the option to create a console app that does not use top-level statements, replace the contents of Program.cs with this code.

In an app with top-level statements, the code in your *Program.cs* file *is not in a namespace*. Every method in a C# program must be inside a class, but it's OK for classes to be outside of namespaces.

We'll learn more about how to work with namespaces later in this chapter.

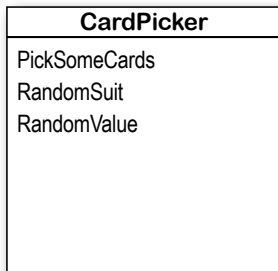
The rest of the console apps in this book will use top-level statements, so when you create the next one make sure to uncheck the "Do not use top-level statements" checkbox.



At the time we're writing this, VSCode does not have the option to create a console app that does not use top-level statements. Just create your console app just like you did in Chapters 1 and 2, then replace the contents of Program.cs with the code we just showed you.

Add a class called CardPicker to your app

The next thing you'll do is add a class called CardPicker to your app. Here's a **class diagram** that shows information about the class you'll build, including the methods that you'll add to your CardPicker class:

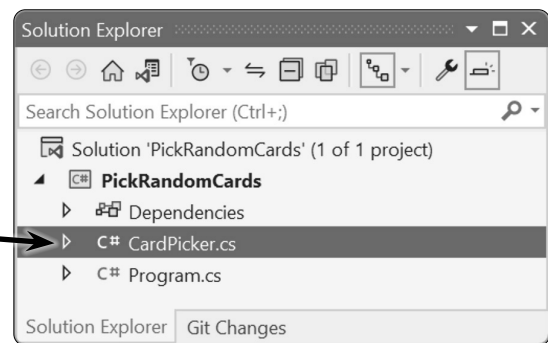
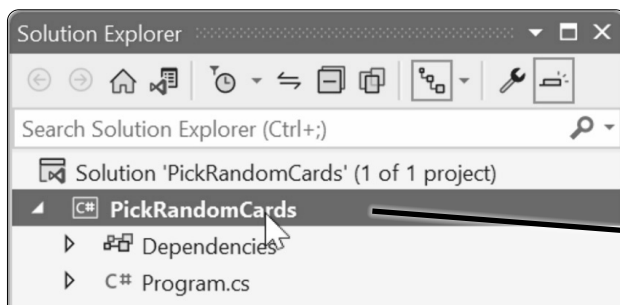


This is a *class diagram*. It's a rectangle with the class name on top and a list of its methods on the bottom. Your CardPicker class will have three methods named PickSomeCards, RandomSuit, and RandomValue.

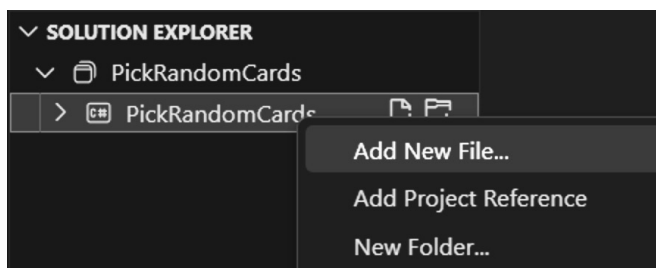
Do this!

Luckily, both Visual Studio and VSCode will help you add a new class to your project.

For Visual Studio: Right-click on the **PickRandomCards** project in the Solution Explorer—it's the *second* row, underneath the solution, which has the same name. When the right-mouse menu pops up, **choose Add >> Class** (or choose *Add Class...* from the Project menu). (If you don't want to do all that clicking, you can also choose Add Class from the Project menu instead of right-clicking on the project name to jump straight to the filename prompt.) **Enter CardPicker.cs** when you're asked for a filename. You should now see a new file called *CardPicker.cs* in your Solution Explorer.



For VSCode: Right-click on the **PickRandomCards** project in the Solution Explorer—it's the *second* row, underneath the solution, which has the same name. When the right-mouse menu pops up, **choose Add New File**, VSCode will display a list of templates at the top of the window and ask you to choose one. Choose **Class**. VSCode will then display a prompt at the top of the window asking you for a filename. **Enter CardPicker.cs**. You should now see a new file called *CardPicker.cs* in your Solution Explorer.



When you right-click on the project name and choose "Add New File..." or click the add file icon next to the project name, VSCode will prompt you for the type of file to add—choose **Class**. Make sure you're in the *Solution Explorer*, not the Explorer.

Sharpen your pencil

Double-click on **CardPicker.cs** in the Solution Explorer to open it. The code in the file will look slightly different depending on whether you used Visual Studio or VSCode.

Here's what your file will look like if you're using Visual Studio:

```

1 using System;
2 using System.Collections.Generic;
3 using System.Linq;
4 using System.Text;
5 using System.Threading.Tasks;
6
7 namespace PickRandomCards
8 {
9     0 references
10    internal class CardPicker
11    {
12    }
13

```

You may not see the "using" lines 1 through 5 in Visual Studio. An update to .NET may have removed them since we took that screenshot. We kept them here for this "Sharpen" exercise.

Here's what it will look like if you're using VSCode:

```

1 namespace PickRandomCards;
2
3 0 references
4 public class CardPicker
5 {
6 }
7

```

Compare the code in these two screenshots. You should be able to spot three important differences. Write them down:

.....

.....

.....

.....

.....

.....

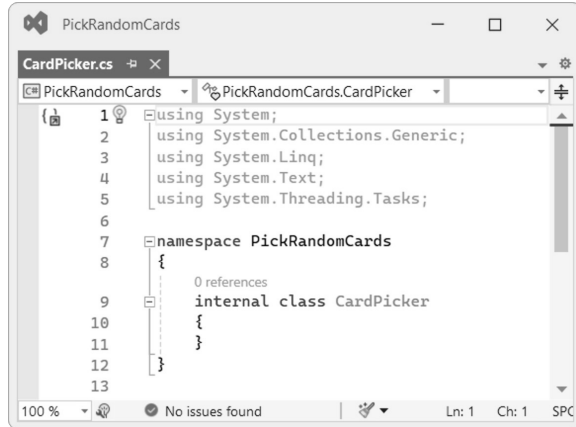
.....

.....

.....

Sharpen your pencil Solution

We asked you to compare the code in two screenshots. Here's the screenshot from Visual Studio:



Did you spot these three differences?

Difference #1: The first five lines in the Visual Studio CardPicker.cs file that start with 'using' are not in the VSCode file.

Difference #2: The 'namespace' line in the VSCode file ends with a semicolon while the same line in Visual Studio is followed by { brackets }.

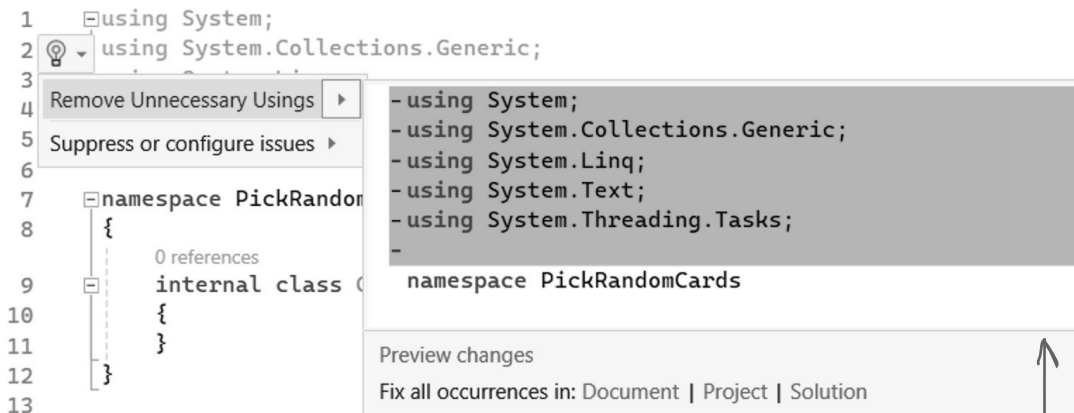
Difference #3: The 'class CardPicker' line starts with 'internal' in VS and 'public' in VSCode.

Use Quick Actions to remove unnecessary using lines

If you're using Visual Studio, you'll see five lines at the top of your *CardPicker.cs* file that start with **using**. These are **using directives**, and you'll learn about them later in the book. But for now, they're not needed.

Luckily, Visual Studio makes it easy to remove those unnecessary using directives from your file, which is good for us because we want to keep things simple and easy to read. Click anywhere in the top five lines. Visual Studio will display the Quick Actions icon to indicate that there's a quick action available.

Choose the **Remove Unnecessary Usings** quick action. Visual Studio will remove the five **using** lines.



If you don't have "using" lines, you can skip this step.

Convert between namespace styles

Let's compare the Visual Studio and VSCode versions of the *CardPicker.cs* file again, this time with the unnecessary using directives at the top of the Visual Studio version removed.

If you're using Visual Studio, your *CardPicker.cs* file uses a **block-scoped namespace**. The **namespace** keyword is followed by the name of the namespace (**PickRandomCards**), which is followed by a block of code inside **{ brackets }** and everything between those brackets is in the **PickRandomCards** namespace.

```
namespace PickRandomCards
{
    internal class CardPicker
    {
    }
}
```

If you're using VSCode, your *CardPicker.cs* file uses a **file-scoped namespace**. The **namespace** keyword is followed by the name of the namespace (**PickRandomCards**) and a semicolon. Everything in the entire file is in the **PickRandomCards** namespace.

```
namespace PickRandomCards;

public class CardPicker
{
}
```

This is the second difference you spotted in the “Sharpen your pencil” exercise. Both ways to define a namespace are valid. They're two different ways to say the same thing: the *CardPicker* class is inside the *PickRandomCards* namespace.

Click on the **namespace** line in your file. You'll see a light bulb or screwdriver icon indicating that there's a quick action available (the icon looks a little different in VSCode). Click the icon (or press **Ctrl+.** or **⌘.**) to bring up the Quick Actions menu:

- ★ If your file has a block-scoped namespace, you'll see a **Convert to file-scoped namespace** quick action.
- ★ If your file has a file-scoped namespace, you'll see a **Convert to block-scoped namespace** quick action.

Choose the quick action to convert to the other namespace style. Then do the same thing and convert it back. Choose the style you like the best—they both work exactly the same way. You can switch namespace styles at any time.

Relax

We'll usually use file-scoped namespaces in the code in this book.

Your code will behave exactly the same whether you use block-scoped or file-scoped namespaces. We'll usually use file-scoped namespaces when we're showing the code in this book, especially in Console App projects, because it takes up less room on the page: file-scoped namespaces don't need the extra lines for the opening and closing brackets, and the code doesn't need to be indented as much.

Also—we didn't talk about the third difference from the “Sharpen your pencil” exercise. The code generated by Visual Studio has the **internal** keyword, while the code generated by VSCode has the **public** keyword. Those are called **access modifiers**. We'll talk more about them later in the book.

use an array to hold multiple cards

Use the new keyword to create an array of strings

Do this!

Let's say you want to create an array of five strings and store it in a variable called `myStrings`.

You can use the **new** keyword to create a new array of strings. You can create your array of five strings like this:

```
string myStrings = new string[5];
```

You can also use a variable, field, or method parameter instead of a number. Your `PickSomeCards` method has a parameter called `numberOfCards`—you'll use that parameter in your new statement: `new string[numberOfCards];`

The `PickSomeCards` method will pick five random cards. Each of the cards will have a random value and a random suit, so the class will also have two more methods that generate the value and suit for each card.

1 Add a new `PickSomeCards` method to your `CardPicker` class.

Put your cursor between the curly brackets, press Enter to add a space, and *carefully* type in this method:

```
internal class CardPicker
{
    public static string[] PickSomeCards(int numberOfCards)
    {
    }
}
```

If you're using VSCode you'll see 'public' instead of 'internal' here. That's OK!

Make sure you include the "public" and "static" keywords. We'll talk more about them later in the chapter.

If you carefully entered your method declaration exactly as it appears here, you should see a red squiggly underline underneath `PickSomeCards`. What do you think it means?

2 Create a new array of strings and store it in a variable called `pickedCards`.

We saw earlier that the `PickSomeCards` method will return an array of strings, so the first thing we'll need is an array of strings to return. Add this line of code to your method:

```
public static string[] PickSomeCards(int numberOfCards)
{
    string[] pickedCards = new string[numberOfCards];
}
```

You'll see a red squiggly line under `PickSomeCards`. Visual Studio is telling you that your method is supposed to return something, but there's no corresponding return statement.

Now the method has a string array to work with.

3 Add a `for` loop to set the value of each card in the array.

Your method has an array of strings. Now it needs to set them. Add this `for` loop—it will call two methods called `RandomValue` and `RandomSuit`. Those methods don't exist yet, but that's OK.

```
public static string[] PickSomeCards(int numberOfCards)
{
    string[] pickedCards = new string[numberOfCards];
    for (int i = 0; i < numberOfCards; i++)
    {
        pickedCards[i] = RandomValue() + " of " + RandomSuit();
    }
}
```

The `RandomValue` and `RandomSuit` methods don't exist yet, so Visual Studio will warn you about them too.

4 Finish the method by adding a return statement.

Add a **return** statement to send the `pickedCards` array back to the statement that called the method.

```
public static string[] PickSomeCards(int numberOfCards)
{
    string[] pickedCards = new string[numberOfCards];
    for (int i = 0; i < numberOfCards; i++)
    {
        pickedCards[i] = RandomValue() + " of " + RandomSuit();
    }
    return pickedCards;
}
```

← Adding the return statement makes the warning on the method declaration line go away, but the warnings for the two method calls are still there.

5 Generate the RandomValue and RandomSuit methods.

In Chapter 2, you generated a method called `OperatorExamples`. Follow exactly the same steps to **generate a method in the `CardPicker` class called `RandomSuit`**. Then do exactly the same thing to generate a method called `RandomValue`.

A method can have *more than one* return statement, and when it executes one of those statements it immediately returns, and does not execute any more statements in the method.

6 Implement the RandomSuit method.

Every card has a suit: hearts, clubs, spades, or diamonds. The `RandomSuit` method will pick a suit at random, store it in a string, and return it. It will use the same random number generator, `Random.Shared`, that you used in Chapter 1 to pick emoji from a list. The random number generator's `Next` method can take two parameters: `random.Next(1, 5)` returns a number that's at least 1 but less than 5—in other words, calling `Random.Shared.Next(1, 5)` returns a random number from 1 to 4.

Let's add code to your `RandomSuit` method that takes advantage of **return** statements to stop executing the method as soon as it finds a match—we added a comment to each line to explain how it works:

```
private static string RandomSuit()
{
    int value = Random.Shared.Next(1, 5); // pick a random number from 1 to 4
    if (value == 1) return "Spades"; // if it's 1 return the string Spades
    if (value == 2) return "Hearts"; // if it's 2 return the string Hearts
    if (value == 3) return "Clubs"; // if it's 3 return the string Clubs
    return "Diamonds"; // otherwise return the string Diamonds
}
```

You used a `Random.Shared` statement in Chapter 1 to choose random emoji from a list.

The return statement causes your method to stop immediately and go back to the statement that called it.

you created a class

7 Implement the RandomValue method.

Every playing card can have one of 13 values—ace, 2 through 10, jack, queen, or king. Here's the RandomValue method that generates a random value. Look closely at it. Can you figure out how it works?

```
private static string RandomValue()
{
    int value = Random.Shared.Next(1, 14);
    if (value == 1) return "Ace";
    if (value == 11) return "Jack";
    if (value == 12) return "Queen";
    if (value == 13) return "King";
    return value.ToString();
}
```

Notice how your method returns `value.ToString()` and not just `value`? That's because `value` is an `int` variable, but the `RandomValue` method was declared with a `string` return type, so we need to convert `value` to a string. You can add `.ToString()` to any variable or value to convert it to a string.

Here's the code for your finished CardPicker class

Your `CardPicker` class is in the `PickRandomCards` namespace and has the methods that we just added:

```
namespace PickRandomCards;
internal class CardPicker
{
```

We're using a file-scoped namespace to make the code take up less space on the page. We also stuck with the "internal" access modifier from Visual Studio, but if you're using VSCode and have "public" that's fine too.

```
    public static string[] PickSomeCards(int numberOfCards)
    {
        string[] pickedCards = new string[numberOfCards];
        for (int i = 0; i < numberOfCards; i++)
        {
            pickedCards[i] = RandomValue() + " of " + RandomSuit();
        }
        return pickedCards;
    }
```

Visual Studio will automatically indent your code for you so it looks like ours. If you're using VSCode, press `Alt+Shift+F` or `\`+Shift+F` to automatically fix the indentation in your file.

```
    private static string RandomSuit()
    {
        int value = Random.Shared.Next(1, 5); // pick a random number from 1 to 4
        if (value == 1) return "Spades"; // if it's 1 return the string Spades
        if (value == 2) return "Hearts"; // if it's 2 return the string Hearts
        if (value == 3) return "Clubs"; // if it's 3 return the string Clubs
        return "Diamonds"; // otherwise return the string
    }
```

```
    private static string RandomValue()
    {
        int value = Random.Shared.Next(1, 14);
        if (value == 1) return "Ace";
        if (value == 11) return "Jack";
        if (value == 12) return "Queen";
        if (value == 13) return "King";
        return value.ToString();
    }
```

We added these comments to help you understand how the `RandomSuit` method works. Try adding similar comments to the `RandomValue` method to explain how it works. We put the comment on each line and used spaces to line them up. You can also put them on separate lines if you think it looks better or is easier to read.

It's OK if your methods are in a different order.

Exercise

Now that your `CardPicker` class has a method to pick random cards, you've got everything you need to finish your console app by **filling in the Main method**. You just need a few useful methods to make your console app read a line of input from the user and use it to pick a number of cards.

Useful method #1: `Console.Write`

You've already seen the `Console.WriteLine` method. Here's its cousin, `Console.Write`, which writes text to the console but doesn't add a new line at the end. You'll use it to display a message to the user:

```
Console.Write("Enter the number of cards to pick: ");
```

Useful method #2: `Console.ReadLine`

The `Console.ReadLine` method reads a line of text from the input and returns a string. You'll use it to let the user tell you how many cards to pick:

```
string? line = Console.ReadLine();
```

← We showed you this line of code earlier in the chapter.

Useful method #3: `int.TryParse`

Your `CardPicker.PickSomeCards` method takes an `int` parameter. The line of input you get from the user is a string, so you'll need a way to convert it to an `int`. You'll use the `int.TryParse` method for that:

```
if (int.TryParse(line, out int numberOfCards))
{
    // this block is executed if line COULD be converted to an int
    // value that's stored in a new variable called numberOfCards
}
else
{
    // this block is executed if line COULD NOT be converted to an int
}
```

← We also showed you this line of code earlier in the chapter.

Put it all together

Your job is to take these three new pieces and put them together in a brand-new `Main` method for your console app. Modify your `Program.cs` file and replace the "Hello, World!" line in the `Main` method with code that does this:

- ★ Use `Console.Write` to ask the user for the number of cards to pick.
- ★ Use `Console.ReadLine` to read a line of input into a string variable called `line`.
- ★ Use `int.TryParse` to try to convert it to an `int` variable called `numberOfCards`.
- ★ If the user input **could be converted** to an `int` value, use your `CardPicker` class to pick the number of cards that the user specified: `CardPicker.PickSomeCards(numberOfCards)`. Use a `string[]` variable to save the results, then use a `foreach` loop to call `Console.WriteLine` on each card in the array. Flip back to Chapter 1 to see an example of a `foreach` loop—you'll use it to loop through every element of the array. Here's the first line of the loop: `foreach (string card in CardPicker.PickSomeCards(numberOfCards))`
- ★ If the user input **could not be converted**, use `Console.WriteLine` to write a message to the user indicating that the number was not valid.

Exercise Solution

Here's the **Main** method for your console app. It replaces the one that Visual Studio created for you that prints "Hello, World!" This method prompts the user for the number of cards to pick, attempts to convert it to an int, and then uses the `PickSomeCards` method in the `CardPicker` class to pick that number of cards. `PickSomeCards` returns each of the picked cards in an array of strings, so it uses a `foreach` loop to write each of them to the console.

```
static void Main(string[] args)
{
    Console.WriteLine("Enter the number of cards to pick: ");
    string? line = Console.ReadLine();
    if (int.TryParse(line, out int numberOfCards))
    {
        string[] cards = CardPicker.PickSomeCards(numberOfCards);
        foreach (string card in cards)
        {
            Console.WriteLine(card);
        }
    }
    else
    {
        Console.WriteLine("Please enter a valid number.");
    }
}
```

We gave you these lines of code.

This is just like the code we showed you earlier, except instead of passing a number like 5 to the method, you're passing it the `numberOfCards` variable.

Here's what it looks like when you run your console app:

```
Microsoft Visual Studio Debug Console
Enter the number of cards to pick: 13
Queen of Hearts
8 of Clubs
6 of Diamonds
King of Spades
5 of Diamonds
8 of Diamonds
9 of Clubs
8 of Hearts
5 of Spades
King of Spades
2 of Clubs
4 of Spades
9 of Spades

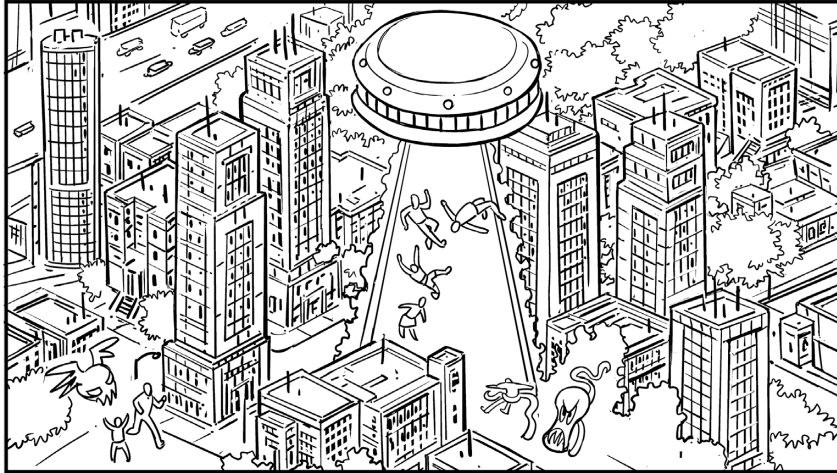
C:\Users\andrewstellman\source\repos\PickRandomCards\PickRandomCards\bin\Debug\net6.0\PickRandomCards.exe (process 4940) exited with code 0.
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

If you're using VSCode, you'll interact with your console app in the Terminal at the bottom of the window. *Click inside the Terminal panel* and type the number of random cards you want your app to pick. If your app is running in the Debug Console window, go back to Chapter 1 and follow the instructions to change the C# debug console setting.

Take the time to really understand how this program works—this is a great opportunity to use the Visual Studio or VSCode debugger to help you explore your code. Place a breakpoint on the first line of the Main method, then use Step Into to step through the entire program. Add a watch for the value variable, and keep your eye on it as you step through the RandomSuit and RandomValue methods.

Ana's working on her next game

Meet Ana. She's an indie game developer. Her last game sold thousands of copies, and now she's getting started on her next one.



In my next game, the player is defending their town from alien invaders.

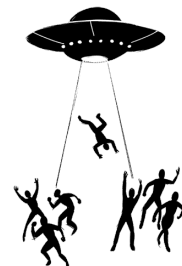
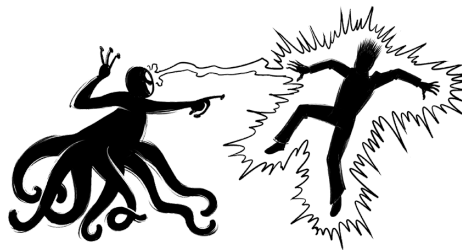


Ana's started working on some **prototypes**. She's been working on the code for the alien enemies that the player has to avoid in one exciting part of the game, where the player needs to escape from their hideout while the aliens search for them. Ana's written several methods that define the enemy behavior: searching the last location where the player was spotted, giving up the search after a while if the player wasn't found, and capturing the player if the enemy gets too close.

```
SearchForPlayer();
```



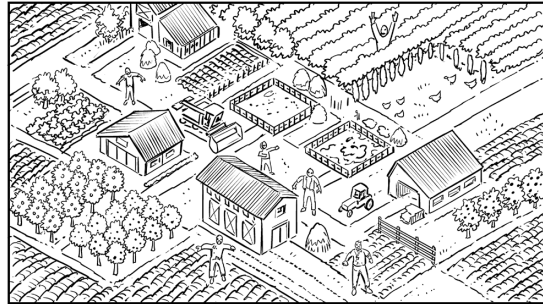
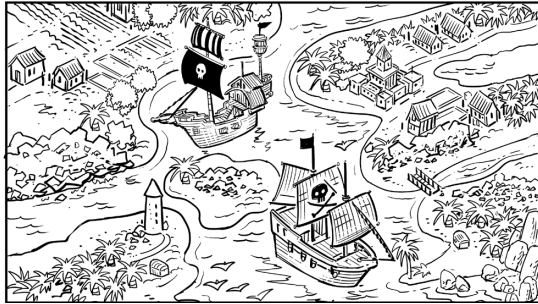
```
if (SpottedPlayer()) {
    CommunicatePlayerLocation();
}
```



```
CapturePlayer();
```

Ana's game is evolving...

The humans versus aliens idea is pretty good, but Ana's not 100% sure that's the direction she wants to go in. She's also thinking about a nautical game where the player has to evade pirates. Or maybe it's a zombie survival game set on a creepy farm. In all three of those ideas, she thinks the enemies will have different graphics, but their behavior can be driven by the same methods.



I bet these enemy methods would work in other kinds of games.

...so how can Ana make things easier for herself?

Ana's not sure which direction the game should go in, so she wants to make a few different prototypes—and she wants them all to have the same code for the enemies, with the `SearchForPlayer`, `StopSearching`, `SpottedPlayer`, `CommunicatePlayerLocation`, and `CapturePlayer` methods. She's got her work cut out for her.



**Brain
Power**

Can you think of a good way for Ana to use the same methods for enemies in different prototypes?



*I put all of the enemy behavior methods into a single Enemy class. Can I **reuse the class** in each of my three different game prototypes?*

Enemy
SearchForPlayer
SpottedPlayer
CommunicatePlayerLocation
StopSearching
CapturePlayer



Game Design...and Beyond

Prototypes

A **prototype** is an early version of your game that you can play, test, learn from, and improve. A prototype can be a really valuable tool to help you make changes early. Prototypes are especially useful because they let you **rapidly experiment with a lot of different ideas** before you've made permanent decisions.

- The first prototype is often a **paper prototype**, where you lay out the core elements of the game on paper. For example, you can learn a lot about your game by using sticky notes or index cards for the different elements of the game, and drawing out levels or play areas on large pieces of paper to move them around.
- One good thing about building prototypes is that they help you get from an idea to a working, playable game very quickly. You **learn the most about a game** (or any kind of program) when you get working software into the hands of your players (or users).
- Most games will go through **many prototypes**. This is your chance to try out lots of different things and learn from them. If something doesn't go well, think of it as an experiment, not a mistake.
- **Prototyping is a skill**, and just like any other skill, you get better at it with practice. Luckily, building prototypes is also fun, and a great way to get better at writing C# code.

Prototypes aren't just used for games! When you need to build **any kind of app**, it's often a great idea to build a prototype first to experiment with different ideas.

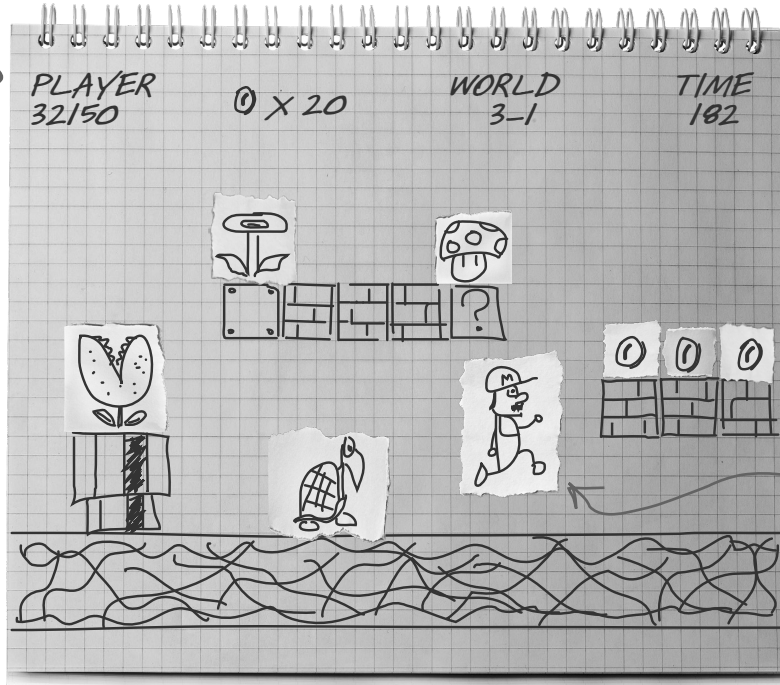
Build a paper prototype for a classic game

Paper prototypes are really useful for helping you figure out how a game will work before you start building it, which can save you a lot of time. There's a fast way to get started building them—all you need is some paper and a pen or pencil. Start by choosing your favorite classic game. Platform games work especially well, so we chose one of the **most popular, most recognizable** classic video games ever made...but you can choose any game you'd like! Here's what to do next.

Draw this!

- 1 Draw the background on a piece of paper.** Start your prototype by creating the background. In our prototype, the ground, bricks, and pipe don't move, so we drew them on the paper. We also added the score, time, and other text at the top.
- 2 Tear small scraps of paper and draw the moving parts.** In our prototype, we drew the characters, the piranha plant, the mushroom, the fire flower, and the coins on separate scraps. If you're not an artist, that's absolutely fine! Just draw stick figures and rough shapes. Nobody else ever has to see this!
- 3 "Play" the game.** This is the fun part! Try to simulate player movement. Drag the player around the page. Make the nonplayer characters move too. It helps to spend a few minutes playing the game, then go back to your prototype and see if you can reproduce the motion as closely as possible. (It will feel a little weird at first, but that's OK!)

The text at the top of the screen is called the HUD, or head-up display. It's usually drawn on the background in a paper prototype.



When the player catches a mushroom he grows to double his size, so we also drew a small character on a separate scrap of paper.



The ground, bricks, and pipe don't move, so we drew them on the background paper. There's no rule about what goes into the background and what moves around.

The mechanics of how the player jumps were really carefully designed. Simulating them in a paper prototype is a valuable learning exercise.

All of the tools and ideas in “Game Design...and Beyond” sections are important skills that go way beyond just game development—but we’ve found that they’re easier to learn when you try them with games first.



Paper prototypes look like they'd be useful for *more than just games*. I bet I can use them in my other projects too.

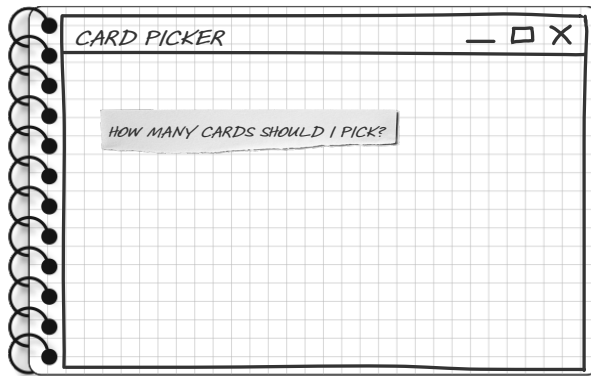
Yes! A paper prototype is a great first step for any project.

If you’re building a desktop app, a mobile app, or any other project that has a user interface, building a paper prototype is a great way to get started. Sometimes you need to create a few paper prototypes before you get the hang of it. That’s why we started with a paper prototype for a classic game...because that’s a great way to learn how to build paper prototypes. **Prototyping is a really valuable skill for any kind of developer**, not just a game developer.

Sharpen your pencil

In the next project, you’ll create a MAUI app that uses your CardPicker class to generate a set of random cards. In this paper-and-pencil exercise, you’ll build a paper prototype of your app to try out various design options.

Start by drawing the window frame on a large piece of paper and a label on a smaller scrap of paper.



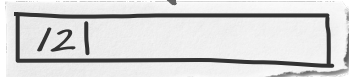
Your app needs to include a Button control with the text “Pick some cards” and a Label control to display the cards somewhere in the window.



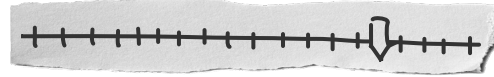
4 OF HEARTS
2 OF DIAMONDS
KING OF SPADES
ACE OF HEARTS
7 OF CLUBS
10 OF SPADES
JACK OF CLUBS
9 OF HEARTS
9 OF DIAMONDS
3 OF CLUBS
ACE OF SPADES

Next, draw a bunch of different types of controls on more small scraps of paper. Drag them around the window and experiment with ways to fit them together. What design do you think works best? There’s no single right answer—there are lots of ways to design any app.

Your app needs a way for the user to choose the number of cards to pick. Try drawing an Entry control that they can use to type numbers into your app.



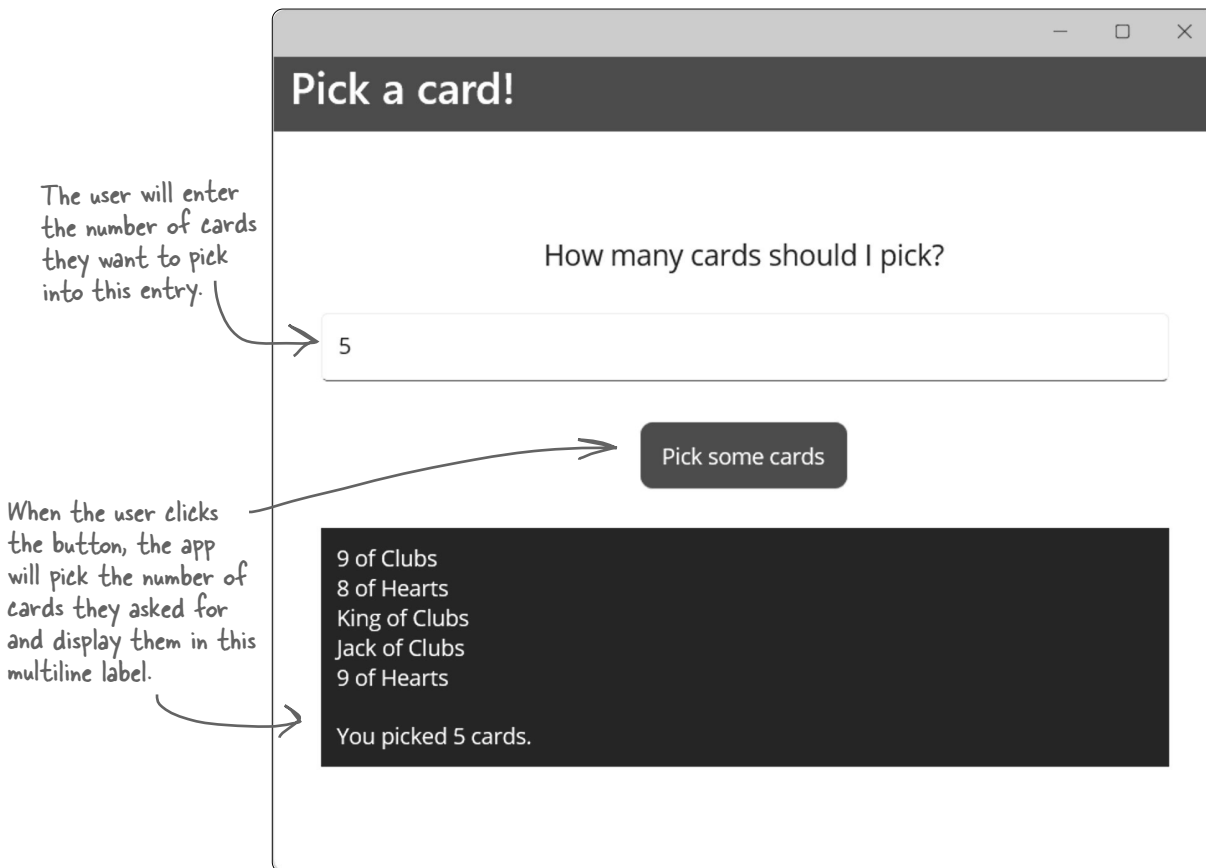
Try drawing Slider and Stepper controls too. Can you think of other controls that you’ve used to input numbers into apps before? Maybe a Picker? Get creative!



Build a MAUI version of your random card app

All of the code for picking random cards is conveniently organized into a class called `CardPicker`. Now you'll **reuse that class** in a .NET MAUI app.

Here's how the app will work.



Make your app accessible!

Accessibility is really important—and paying attention to accessibility is a great way to focus on important skills, like understanding your users and their needs:

- ★ The Label and Entry controls each have a **SemanticProperties.Description property** so the screen reader will read it out loud.
- ★ The Button control has a **SemanticProperties.Hint property** because the screen reader will read the contents of the button but we still want to give people who use accessibility tools additional context for the control.

Exercise

You already have the tools you need to create the XAML for the MAUI card picker app! In this exercise, you'll use what you learned about XAML in the first two chapters to create the main page for your app. You may need to go back to the XAML code you wrote in Chapter 2 to see how you added controls to your page.

Create a new .NET MAUI app called **PickRandomCardsMAUI**. Edit the *MainPage.xaml.cs* file to delete the controls inside the *VerticalStackLayout* (just like you did in Chapter 2), then add the controls for your card picker app.

*Bonus: Edit the *AppShell.xaml* file to set the page title! We haven't shown you how to do that yet—can you figure it out?*

The *ContentPage* contains a *ScrollView*, which contains a *VerticalStackLayout*, just like your last MAUI project.

Can you figure out how to set the page title? Open the *AppShell.xaml* file, look for a `<ShellContent>` tag, and change its `Title` property.

Pick a card!

This is a *Label* with `FontSize 18`. Make sure you give it a `SemanticProperties.Description`. Set its `HorizontalOptions` property to "Center" so it gets centered in the window.

This is an *Entry*. Give it a placeholder and a semantic description for accessibility, and use the `x:Name` property to name it "NumberOfCards" so your code can read its value.

How many cards should I pick?

Don't forget to *delete everything* in the *MainPage.xaml.cs* file except for the *MainPage* method.

Enter the number of cards to pick

Pick some cards

This *Button* has the name "PickCardsButton" and a *Clicked* event handler method called *PickCardsButton_Clicked*. Make sure the event handler method is created in *MainPage.xaml.cs*. Set its `HorizontalOptions` property to "Center" and give it a `SemanticProperties.Hint` property.

This is a multiline *Label* with the name "PickedCards" and a `Padding` property to 20 so it has some space around the text. It has white text on a dark blue background. Make sure it has a `SemanticProperties.Description`.

Peeking at the solution is *not cheating*! It's actually a great way to get these ideas to stick in your brain.

Exercise Solution

Your *MainPage.xaml.cs* file should have a public `MainPage()` method that calls `InitializeComponent` and an empty `Clicked` event handler method and nothing else.

Here's the XAML for the contents of *MainPage.xaml* (we didn't include the outer `<ContentPage>` tag):

```
<ScrollView>
  <VerticalStackLayout
    Spacing="25"
    Padding="30,0"
    VerticalOptions="Center">
    <Label
      Text="How many cards should I pick?"
      SemanticProperties.Description="How many cards should I pick?"
      FontSize="18"
      HorizontalOptions="Center" />
    <Entry
      x:Name="NumberOfCards"
      SemanticProperties.Description="Enter the number of cards to pick"
      Placeholder="Enter the number of cards to pick" />
    <Button
      x:Name="PickCardsButton"
      Text="Pick some cards"
      SemanticProperties.Hint="Picks some cards"
      Clicked="PickCardsButton_Clicked"
      HorizontalOptions="Center" />
    <Label x:Name="PickedCards" Padding="20"
      TextColor="White" BackgroundColor="DarkBlue"
      SemanticProperties.Description="Shows the cards that were picked" />
  </VerticalStackLayout>
</ScrollView>
```

These are the same `ScrollView` and `VerticalStackLayout` tags that Visual Studio created using the .NET MAUI template.

The `HorizontalOptions` property centers the label on the page. Try the other options—do you like the way they look better?

You gave the `Entry`, `Button`, and `Label` controls names that you'll use in your C# code.

Make sure Visual Studio added the `PickCardsButton_Clicked` event handler method that gets called when the button is clicked. You'll use it in the second part of this project. If you're using VSCode you might need to carefully type it yourself, just like you did with the other MAUI projects.

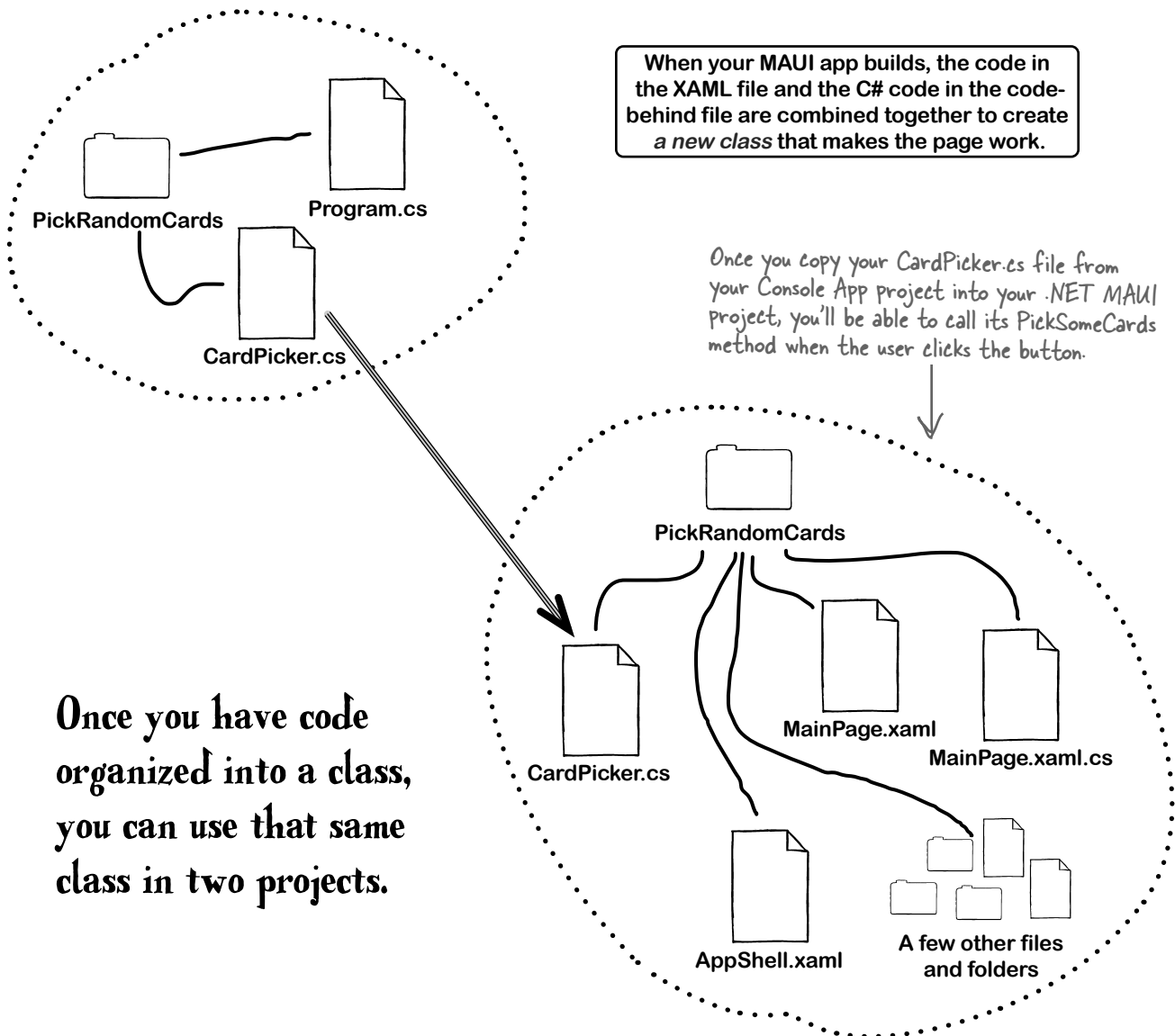
We made this change to *AppShell.xaml* to set the title of the page to "Pick a card!":

```
<?xml version="1.0" encoding="UTF-8" ?>
<Shell
  ...
  Shell.FlyoutBehavior="Disabled" BackgroundColor="Red">
  <ShellContent
    Title="Pick a card!"
    ContentTemplate="{DataTemplate local:MainPage}"
    Route="MainPage" />
</Shell>
```

The XAML in *AppShell.xaml* tells your MAUI app what to do when it first starts up. The `ShellContent`'s `Route` property tells it to load the page in your *MainPage.xaml* file. Try setting the `BackgroundColor` of the outer `Shell` tag—what does that change in the app?

Make your MAUI app pick random cards

You've got an app that looks like it's supposed to, and that's a great start! In the second part of this project, you'll make it work, so when the user enters a number and clicks the button it picks random cards. That's where your `CardPicker` class comes in. You've already created a class that picks random cards. Now you just need to **copy that class into your new APP**. Once it's copied, you'll be able to make your button's event handler method call the `PickSomeCards` method in the `CardPicker` class.



Once you have code organized into a class, you can use that same class in two projects.

Reuse your CardPicker class

You took the time to put all of the random card picking code into a convenient class. Now it's time to **reuse that class** by *copying the file* with the C# code into your new MAUI project.



1 Choose Add Existing Item in Visual Studio or manually copy the file in VSCode.

This feature in the IDE will copy an existing file into your project. You created a file called *CardPicker.cs* in your *PickRandomCards* console app. Now you'll tell the IDE to **add that class file** to your MAUI project, which will cause it to copy the file into your MAUI app's project folder.

- ★ In Visual Studio, right-click on the project in the Solution Explorer window and choose Add >> Existing Item (Shift+Alt+A), or choose Add Existing Item from the Project menu.
- ★ In VSCode, you'll need to manually copy the file into the folder. Right-click on the project in the Solution Explorer and choose "Reveal in File Explorer" (or "Reveal in Finder" if you're using a Mac). Use your operating system to copy the file into your project folder that VSCode opened. Once the file is copied, it will automatically appear in the Solution Explorer.

2 Find your *CardPicker.cs* file and add it to your project.

The IDE will pop up a folder explorer window. Navigate to the folder with your *PickACard* console app and **double-click on CardPicker.cs**. You should now see *CardPicker* in the Solution Explorer.

Make sure *CardPicker.cs* now shows up in your Solution Explorer. Open it and make sure that you see the code for the *CardPicker* class from earlier in the chapter.

3 Try to use your *CardPicker* class in the *MainPage.xaml.cs* code.

Open *MainPage.xaml.cs*. Make sure you've deleted everything inside the *MainPage* class except the *MainPage* method (starting with **public MainPage()** and ending with a closing bracket). Edit the *PickCardsButton_Clicked* event handler method and try adding a statement that calls your *CardPicker.PickSomeCards* method.

```
public partial class MainPage : ContentPage
{
    public MainPage()
    {
        InitializeComponent();
    }

    private void PickCardsButton_Clicked(object sender, EventArgs e)
    {
        CardPicker.
    }
}
```

Here's the event handler method that Visual Studio added to your C# code when you added a Clicked event handler to the XAML for the button. If you're using VSCode, you'll need to carefully type the empty method into your *MainPage.xaml.cs* file.

Hold on—something's wrong!

When you start typing the statement to call *CardPicker.PickSomeCards*, Visual Studio doesn't pop up its normal IntelliSense window, and there's a squiggly error line under *CardPicker*.

Why do you think Visual Studio is treating *CardPicker* like that?

Add a using directive to use code in another namespace

You used either a **file-scoped namespace** or **block-scoped namespace** to put your `CardPicker` class in the `PickRandomCards` namespace. Compare the namespace declaration in your `CardPicker` class to the code at the top of your `MainPage.xaml.cs` file in your MAUI app:

```
namespace PickRandomCardsMAUI;

public partial class MainPage : ContentPage
{
    ... your MAUI app's code is in the PickRandomCardsMAUI namespace ...
}
```

The reason your `MainPage` class can't access the methods in your `CardPicker` class is because *they're in different namespaces*.

Luckily, C# has an easy way to deal with this. You'll add a **using directive** in your code that calls the methods in `CardPicker`—that's a special line that you put at the top of a class file to tell it to use code in another namespace.

Add this line to the top of your `MainPage.xaml.cs` file.

If you chose a different name for your console app, replace `PickRandomCards` with the namespace in your `CardPicker.cs` file.

```
using PickRandomCards;
```

Now go back to the event handler method for your button. Start typing `CardPicker.` like you did before. Now Visual Studio will pop up its IntelliSense window, just like you'd expect it to.

Add
this!

This *using directive* will let you add code to your `MainPage.xaml.cs` file that uses classes in the `PickRandomCards` namespace—so now you can write code that calls methods in your `CardPicker` class. You might see other *using directives* at the top of the file too.

Exercise

Here's a C# coding challenge for you! Now that you added the `using` directive to the top of your `MainPage.xaml.cs` file, code in that file can use the `CardPicker` class. Can you finish your event handler method to make your app work?

To do this, you'll need to add statements to the `PickCardsButton_Clicked` event handler method. Here's what to do:

- The first thing the method does is call `int.TryParse` to convert `NumberOfCards.Text` to a number.
- If the number is valid, it calls `CardPicker.PickSomeCards` just like in your console app. If it isn't, it makes the `PickedCards` label display a message: `PickedCards.Text = "Please enter a valid number.";`
- Instead of writing to the console, it sets `PickedCards.Text` to a string value to make text appear in the `PickedCards` Label control. You can clear the text in `PickedCards` like this: `PickedCards.Text = String.Empty;`
- After it clears the `PickedCards` label, it uses a `foreach` loop that works just like the one in your console app.
- Add this statement after the `foreach` loop to tell the user how many cards they picked:
`PickedCards.Text += Environment.NewLine + "You picked " + numberOfCards + " cards.";`

Exercise Solution

Here's the finished event handler method.

```
private void PickCardsButton_Clicked(object sender, EventArgs e)
{
    if (int.TryParse(NumberOfCards.Text, out int numberOfCards))
    {
        string[] cards = CardPicker.PickSomeCards(numberOfCards);
        PickedCards.Text = String.Empty;
        foreach (string card in cards)
        {
            PickedCards.Text += card + Environment.NewLine;
        }
        PickedCards.Text += Environment.NewLine + "You picked " + numberOfCards + " cards.";
    }
    else
    {
        PickedCards.Text = "Please enter a valid number.";
    }
}
```

Now that you have a using directive at the top of your MainPage.xaml.cs file, you can use the CardPicker class.

The foreach loop works just like the one in the console app, except instead of writing a line of text to the console it adds a line to the multi-line PickedCards Label control.

Bullet Points

- Classes have methods that contain statements that perform actions. Well-designed classes have sensible method names.
- Some methods have a **return type**. You set a method's return type in its declaration. A method with a declaration that starts with the `int` keyword returns an `int` value. Here's a statement that returns an `int` value: `return 37;`
- When a method has a return type, it **must** have a `return` statement that returns a value that matches a return type. So if a method declaration has the `string` return type then you need a `return` statement that returns a `string`.
- As soon as a `return` statement in a method executes, your program jumps back to the statement that called the method.
- Not all methods have a return type. A method with a declaration that starts `public void` doesn't return anything at all. You can still use a `return` statement to exit a void method, as in this example: `if (finishedEarly) { return; }`
- Developers often **reuse** the same code in multiple programs. Classes can help you make your code more reusable.
- When you **select a control** in the XAML code editor, you can edit its properties in the Properties window.
- The XAML code combines with the C# code in the code-behind file to **create a new class**.
- You can create an array of values using a **collection expression** by putting the values between a pair of square brackets [] and separating them with commas.
- The **global namespace** contains the top-level statements and any class not explicitly put into a namespace using a namespace declaration.

Ana's prototypes look great...

Ana found out that whether her player was being chased by an alien, a pirate, a zombie, or an evil killer clown, she could use the same methods from her Enemy class to make them work. Her game is starting to shape up.

Enemy
SearchForPlayer
SpottedPlayer
CommunicatePlayerLocation
StopSearching
CapturePlayer

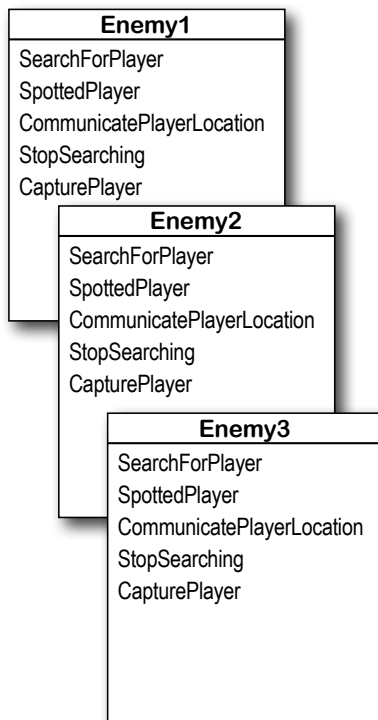
...but what if she wants more than one enemy?

And that's great...until Ana wants more than one enemy, which is all there was in each of her early prototypes. What should she do to add a second or third enemy to her game?

Ana *could* copy the Enemy class code and paste it into two more class files. Then her program could use methods to control three different enemies at once. Technically, we're reusing the code...right?

Hey Ana, what do you think of that idea?

She has a point. What if she wants a level with, say, dozens of zombies? Creating dozens of identical classes just isn't practical.



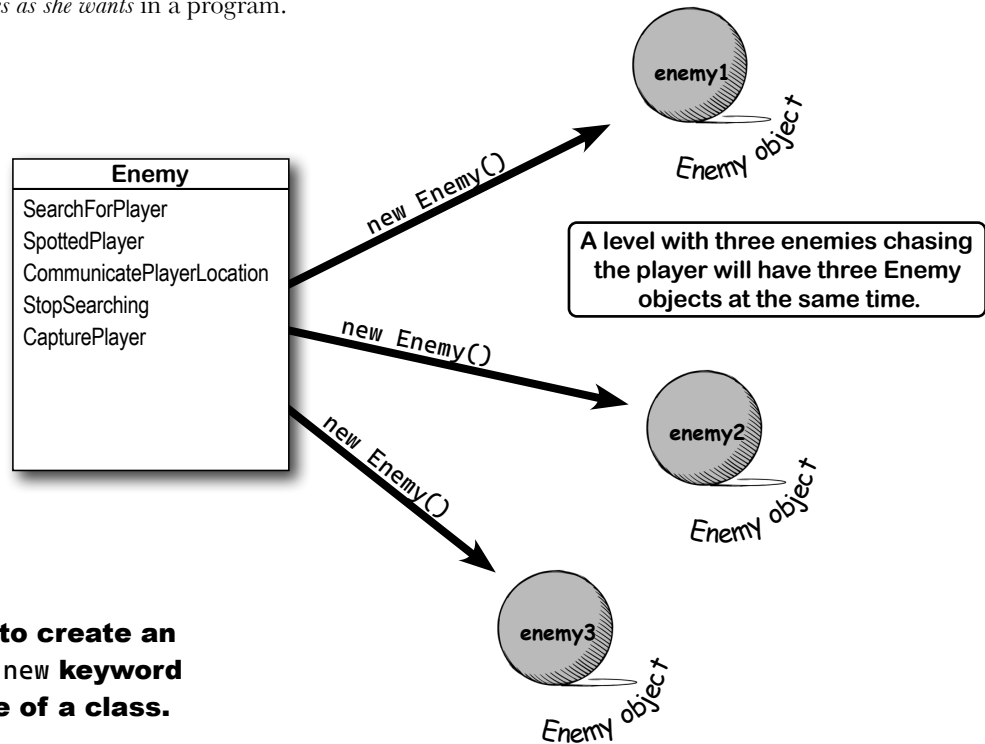
Are you joking? Using separate identical classes for each enemy is a **terrible idea**. What if I want more than three enemies at once?

Maintaining three copies of the same code is really messy.

A lot of problems you have to solve need a way to represent one **thing** a bunch of different times. In this case, it's an enemy in a game, but it could be songs in a music player app, or contacts in a social media app. Those all have one thing in common: they always need to treat the same kind of thing in the same way, no matter how many of that thing they're dealing with. Let's see if we can find a better solution.

Ana can use objects to solve her problem

Objects are C#'s tool that you use to work with a bunch of similar things. Ana can use objects to program her Enemy class just once, and use it *as many times as she wants* in a program.



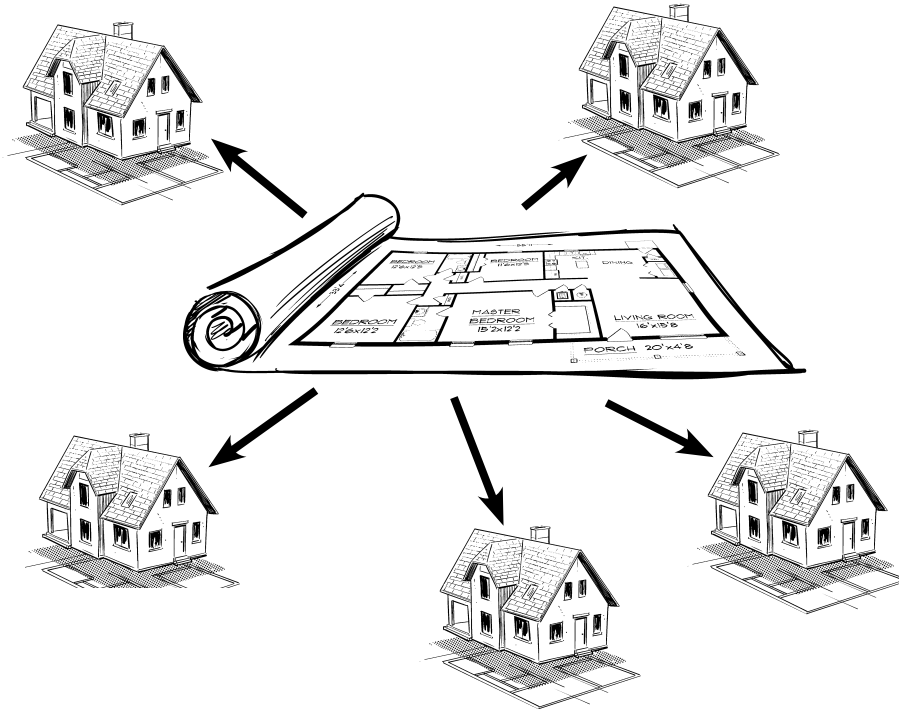
All you need to create an object is the `new` keyword and the name of a class.

```
Enemy enemy1 = new Enemy();  
enemy1.SearchForPlayer();  
if (enemy1.SpottedPlayer()) {  
    enemy1.CommunicatePlayerLocation();  
} else {  
    enemy1.StopSearching();  
}
```

Now you can use the object! When you create an object from a class, that object has all of the methods from that class.

You use a class to build an object

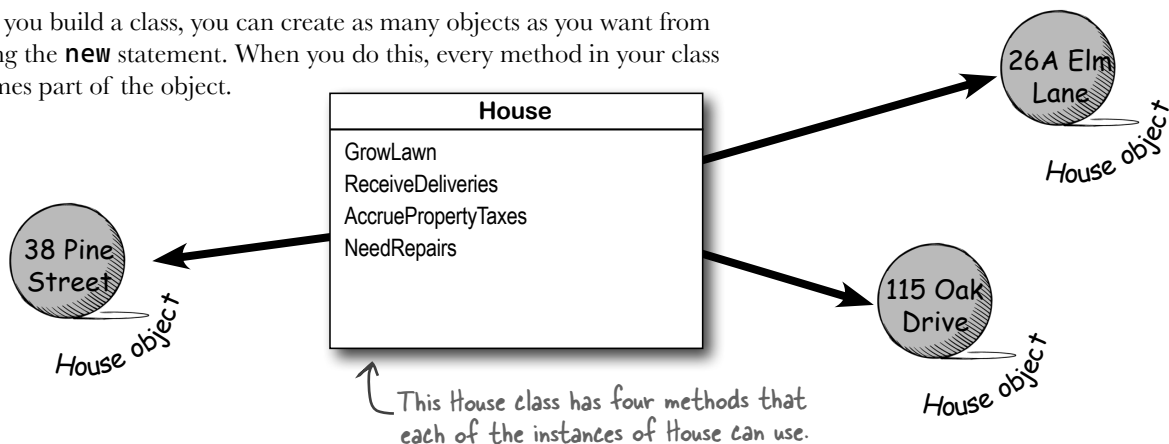
A class is like a blueprint for an object. If you wanted to build five identical houses in a suburban housing development, you wouldn't ask an architect to draw up five identical sets of blueprints. You'd just use one blueprint to build five houses.



A class defines its members, just like a blueprint defines the layout of the house. You can use one blueprint to make any number of houses, and you can use one class to make any number of objects.

An object gets its methods from its class

Once you build a class, you can create as many objects as you want from it using the **new** statement. When you do this, every method in your class becomes part of the object.



When you create a new object from a class, it's called an instance of that class

You use the **new keyword** to create an object. All you need is a variable to use with it. Use the class as the variable type to declare the variable, so instead of int or bool, you'll use a class like House or Enemy.

Before: here's a picture of your computer's memory when your program starts.



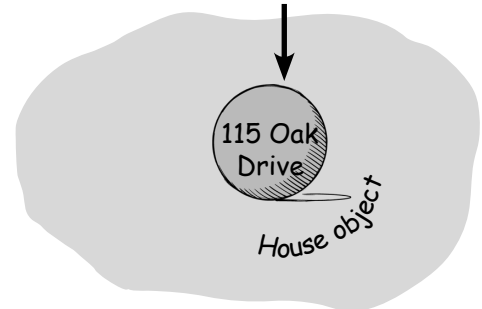
Your program executes a new statement.

```
House oakDrive115 = new House();
```

This "new" statement creates a new House object and assigns it to a variable called oakDrive115.

in-stance, noun.
an example or one occurrence of something. *The IDE search-and-replace feature finds every **instance** of a word and changes it to another.*

After: now it has an instance of the House class in memory.



A better solution for Ana...brought to you by objects

Ana used objects to reuse the code in the Enemy class without all that messy copying that would've left duplicate code all over her project. Here's how she did it.

- 1 Ana created a Level class that stored the enemies in an **Enemy array** called **enemyArray**, just like you used string arrays to store cards and animal emoji.

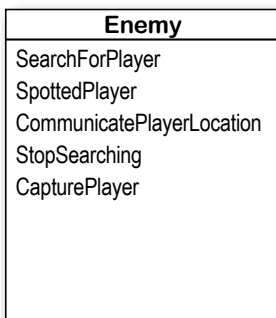
```
internal class Level {
    Enemy[] enemyArray = new Enemy[3];
```

Use the name of a class to declare an array of instances of that class.

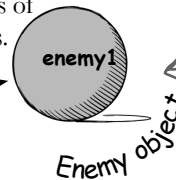
We're using the "new" keyword to create an array of Enemy objects, just like you did earlier with strings.

Hmm, this array is inside the class, but outside of the methods. What do you think is going on?

- 2 She used a loop that called **new** statements to create new instances of the Enemy class for the level and add them to an array of enemies.



new Enemy()



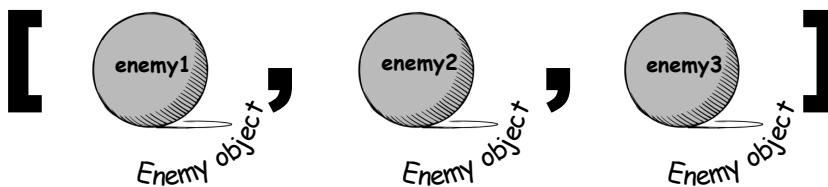
The enemy1 object is an instance of the Enemy class.

```
for (int i = 0; i < 3; i++)
{
    Enemy enemy = new Enemy();
    enemyArray[i] = enemy;
}
```

This statement uses the new keyword to create an Enemy object.

This statement adds the newly created Enemy object to the array.

- 3 She called methods of each Enemy instance during every frame update to implement the enemy behavior.



```
foreach (Enemy enemy in enemyArray)
{
    // code that calls the Enemy methods
}
```

The foreach loop iterates through the array of Enemy objects.



When you create a new instance of a class, it's called **instantiating** that class.



Wait a minute! You didn't give me *nearly enough information* to build Ana's game.

That's right, we didn't.

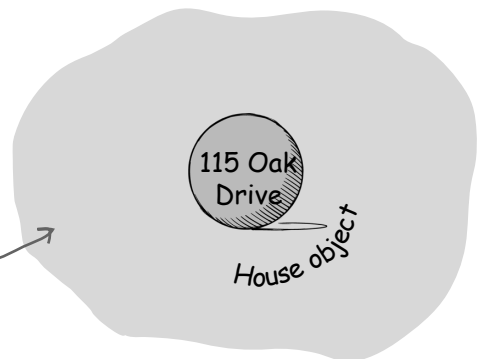
Some game prototypes are really simple, while others are much more complicated—but complicated programs follow the same patterns as simple ones. Ana's game program is an example of how someone would use objects in real life. And this doesn't just apply to game development! No matter what kind of program you're building, you'll use objects in exactly the same way that Ana did in her game. Ana's example is just the starting point for getting this concept into your brain. We'll give you **lots more examples** over the rest of the chapter—and this concept is so important that we'll revisit it in future chapters too.

Theory and practice

Speaking of patterns, here's a pattern that you'll see over and over again throughout the book. We'll introduce a concept or idea (like objects) over the course of a few pages, using pictures and short code excerpts to demonstrate the idea. This is your opportunity to take a step back and try to understand what's going on without having to worry about getting a program to work.

```
House oakDrive115 = new House();
```

When we're introducing a new concept (like objects), keep your eyes open for pictures and code excerpts like these.

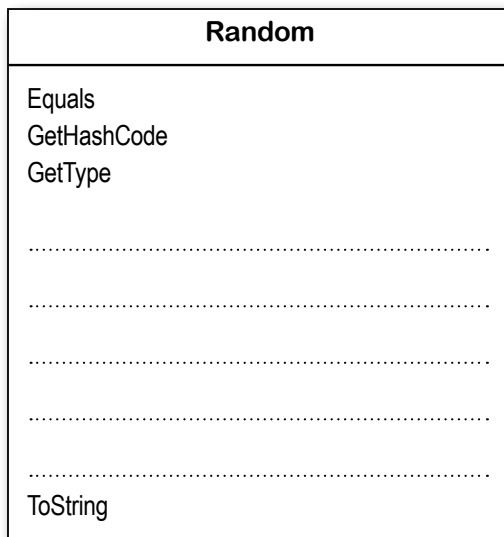




Sharpen your pencil

Now that you've got a better idea of how objects work, it's a great time to go back to your CardPicker class and get to know the Random class that you're using.

1. Open any Console App project that uses top-level statements (or create a new one). Press Enter to start a new statement, then type `Random.Shared`. —as soon as you type the second period, Visual Studio will pop up an IntelliSense window that shows its methods. Each method is marked with a cube icon (📦). We filled in some of the methods. Finish filling in the class diagram for the Random class.



In Chapter 2, we showed you three types, `int` (for whole numbers), `string` (for text), and `bool` (for true/false values). A *double* is another type that's used for numbers with decimal places. The computer science term for a number with decimal places is a *floating-point number*. You'll learn about more types in the next chapter.

2. Write code to create a new array of doubles called `randomDoubles`, then use a `for` loop to add 20 double values to that array. Use the IntelliSense pop-up to help you choose the right method from the Random class to use in your code—make sure you're calling the method that returns a random floating-point number that is greater than or equal to 0.0, and less than 1.0. (We'll talk about what "floating point" means in the next chapter.)

```
double[] randomDoubles = new double[20];
.....
{
    double value =
.....
}
```

We filled in part of the code, including the curly braces. Your job is to finish those statements and then write the rest of the code.

Sharpen your pencil Solution

Now that you've got a better idea of how objects work, it's a great time to go back to your CardPicker class and get to know the Random class that you're using.

1. Open any Console App project that uses top-level statements (or create a new one). Press Enter to start a new statement, then type `Random.Shared`. —as soon as you type the second period, Visual Studio will pop up an IntelliSense window that shows its methods. Each method is marked with a cube icon (📦). We filled in some of the methods. Finish filling in the class diagram for the Random class.

Random

Equals
GetHashCode
GetType

.....
Next
.....

.....
NextBytes
.....

.....
NextDouble
.....

.....
NextInt64
.....

.....
NextSingle
.....

ToString

Random.Shared.

Here's the IntelliSense window that Visual Studio popped up when you typed `Shared.Random`.

When you select `NextDouble` in the IntelliSense window, it shows documentation for the method.

📦 Equals

📦 GetHashCode

📦 GetType

📦 Next

📦 NextBytes

📦 **NextDouble**

📦 NextInt64

📦 NextSingle

📦 ToString

`double Random.NextDouble()`
Returns a random floating-point number that is greater than or equal to 0.0, and less than 1.0.

2. Write code to create a new array of doubles called **randomDoubles**, then use a **for** loop to add 20 double values to that array. Use the IntelliSense pop-up to help you choose the right method from the Random class to use in your code—make sure you're calling the method that returns a random floating-point number that is greater than or equal to 0.0, and less than 1.0. (We'll talk about what "floating point" means in the next chapter.)

```

double[] randomDoubles = new double[20];
.....
for (int i = 0; i < 20; i++)
.....
{
.....
    double value = Random.Shared.NextDouble();
.....
    randomDoubles[i] = value;
.....
}
.....
    
```

This is really similar to the code that you used in your CardPicker class.

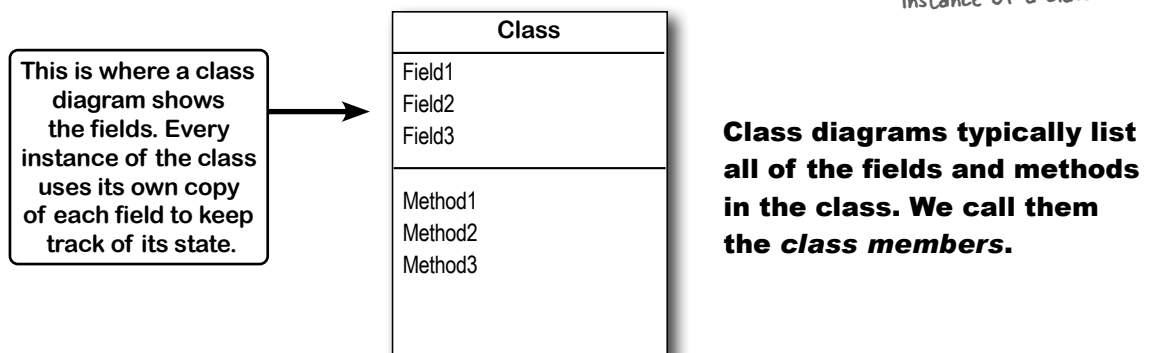
An instance uses fields to keep track of things

We just saw an example of a House class that's used to instantiate House objects. Each house needs to remember its address: the 38 Pine Street instance of House needs to store its specific address, while the 115 Oak Drive instance needs to remember a different one.

This is where fields come in—they store the data that each instance of the class needs to keep track of. Every time you instantiate the class, the new instance that was created gets its own copy of that **field**,

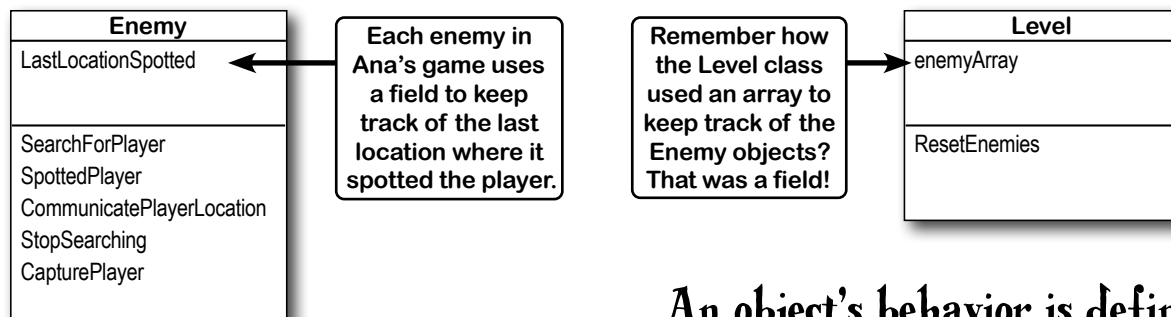
When we want to include fields in a class diagram, we'll draw a horizontal line in the box. The fields go above the line, and methods go below the line.

Sometimes people think the word "instantiate" sounds a little weird, but it makes sense when you think about what it means: creating a new instance of a class.



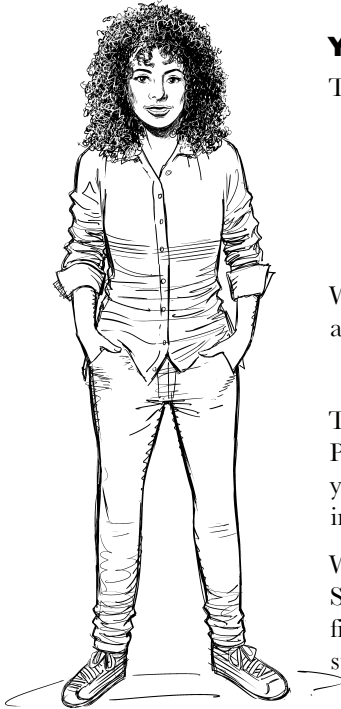
Methods are what an object does. Fields are what an object knows.

When Ana's prototype created three instances of her Enemy class, each of those objects was used to keep track of a different enemy in the game. Every instance keeps separate copies of the same data: setting a field on the enemy2 instance won't have any effect on the enemy1 or enemy3 instances.



An object's behavior is defined by its methods, and it uses fields to keep track of its state.

I used the **new** keyword to create an instance of *Random*, but I **never** created a **new instance** of my *CardPicker* class. So does that mean I can call methods without creating objects?



Yes! That's why you used the **static** keyword in your declarations.

Take another look at the method declarations in your *CardPicker* class:

```
public static string[] PickSomeCards(int numberOfCards)
```

```
private static string RandomValue()
```

```
private static string RandomSuit()
```

When you use the **static** keyword to declare a field or method in a class, you don't need an instance of that class to access it. You just called your method like this:

```
CardPicker.PickSomeCards(numberOfCards)
```

That's how you call static methods. If you take away the **static** keyword from the *PickSomeCards* method declaration, then you'll have to create an instance of *CardPicker* you can use to call the method. Other than that distinction, static methods are just like instance methods: they can take arguments, they can return values, and they live in classes.

When a field is static **there's only one copy of it, and it's shared by all instances**. So if you created multiple instances of *CardPicker*, they would all share the same *random* field. You can even mark your **whole class** as static, and then all of its members **must** be static too. If you try to add a nonstatic method to a static class, your program won't build.

there are no Dumb Questions

Q: When I think of something that's "static," I think of something that doesn't change. Does that mean nonstatic methods can change, but static methods don't? Do they behave differently?

A: No, both static and nonstatic methods act exactly the same. The only difference is that static methods don't require an instance, while nonstatic methods do.

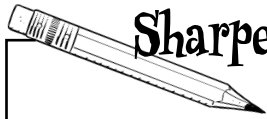
Q: So I can't use my class until I create an instance of an object?

A: You can use its static methods, but if you have methods that aren't static, then you need an instance before you can use them.

Q: Then why would I want a method that needs an instance? Why wouldn't I make all my methods static?

A: Because if you have an object that's keeping track of certain data—like Ana's instances of her *Enemy* class that each kept track of different enemies in her game—then you can use each instance's methods to work with that data. So when Ana's game calls the *StopSearching* method on the *enemy2* instance, it only causes that one enemy to stop searching for the player. It doesn't affect the *enemy1* or *enemy3* objects, and they can keep searching. That's how Ana can create game prototypes with any number of enemies, and her programs can keep track of all of them at once.

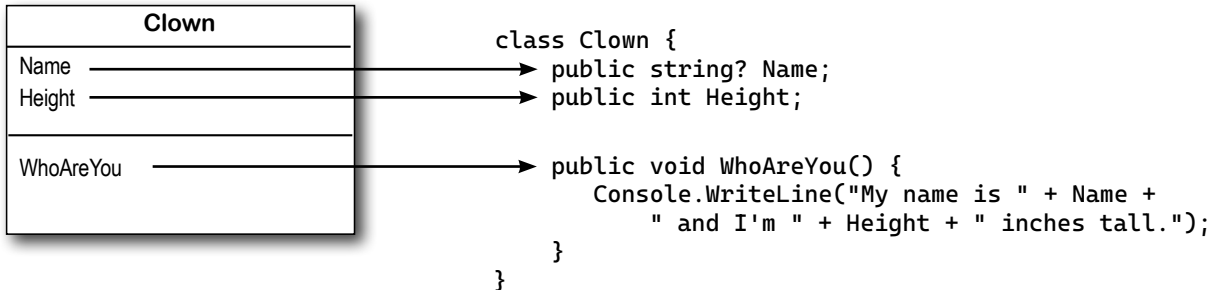
When a field is static, there's only one copy of it shared by all instances.



Sharpen your pencil

Here's a console app that uses top-level statements and writes several lines to the console. It includes a class called `Clown` that has two fields, `Name` and `Height`, and a method called `WhoAreYou` that uses those fields to write a line to the console. Your job is to read the code and **write down the lines that are printed to the console**.

Here's the class diagram and code for the `Clown` class:



Here are the contents of the `Program.cs` file. There are comments next to each of the calls to the `WhoAreYou` method, which prints a line to the console. Your job is to fill in the blanks in the comments so they match the output.

```

Clown oneClown = new Clown();
oneClown.Name = "Boffo";
oneClown.Height = 14;
oneClown.WhoAreYou();      // My name is _____ and I'm ____ inches tall.

```

```

Clown anotherClown = new Clown();
anotherClown.Name = "Biff";
anotherClown.Height = 16;
anotherClown.WhoAreYou(); // My name is _____ and I'm ____ inches tall.

```

```

Clown clown3 = new Clown();
clown3.Name = anotherClown.Name;
clown3.Height = oneClown.Height - 3;
clown3.WhoAreYou();      // My name is _____ and I'm ____ inches tall.

```

```

anotherClown.Height *= 2;
anotherClown.WhoAreYou(); // My name is _____ and I'm ____ inches tall.

```

The `*=` operator tells C# to take whatever's on the left of the operator and multiply it by whatever's on the right, so this will update the `Height` field.



toss your new object onto the heap of data

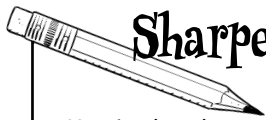
Thanks for the memory

When your program creates an object, it lives in a part of the computer's memory called the **heap**. When your code creates an object with a **new** statement, C# immediately reserves space in the heap so it can store the data for that object.

Here's a picture of the heap before the project starts. Notice that it's empty.



When your program creates a new object, it gets added to the heap.



Sharpen your pencil Solution

Here's what the program prints to the console. It's worth taking a few minutes to create a new console app—make sure it uses top-level statements—add the Clown class, and make its *Program.cs* method the code below. Then step through it with the debugger so you can see exactly how it works.

```
Clown oneClown = new Clown();
oneClown.Name = "Boffo";
oneClown.Height = 14;
oneClown.WhoAreYou(); // My name is Boffo and I'm 14 inches tall.

Clown anotherClown = new Clown();
anotherClown.Name = "Biff";
anotherClown.Height = 16;
anotherClown.WhoAreYou(); // My name is Biff and I'm 16 inches tall.

Clown clown3 = new Clown();
clown3.Name = anotherClown.Name;
clown3.Height = oneClown.Height - 3;
clown3.WhoAreYou(); // My name is Biff and I'm 11 inches tall.

anotherClown.Height *= 2;
anotherClown.WhoAreYou(); // My name is Biff and I'm 32 inches tall.
```

What's on your app's mind

Let's take a closer look at the program in the "Sharpen your pencil" exercise, starting with the first line of the app. It's actually **two statements** combined into one:

```
Clown oneClown = new Clown();
```

This is a statement that declares a variable called `oneClown` of type `Clown`.

This statement creates a new object and assigns it to the `oneClown` variable.

Next, let's look closely at what the heap looks like after each group of statements is executed:

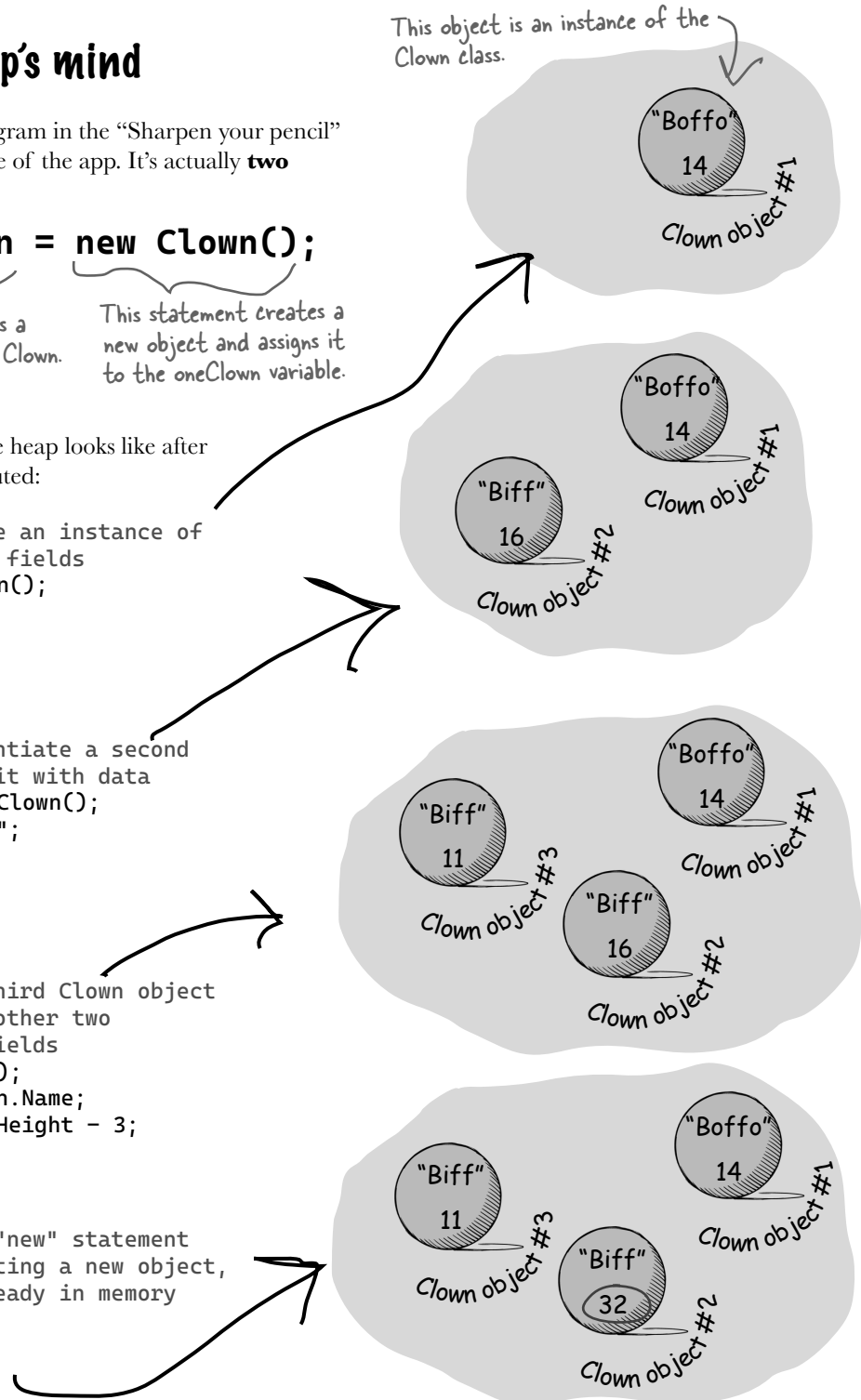
```
// These statements create an instance of
// Clown and then set its fields
Clown oneClown = new Clown();
oneClown.Name = "Boffo";
oneClown.Height = 14;
oneClown.WhoAreYou();
```

```
// These statements instantiate a second
// Clown object and fill it with data
Clown anotherClown = new Clown();
anotherClown.Name = "Biff";
anotherClown.Height = 16;
anotherClown.WhoAreYou();
```

```
// Now we instantiate a third Clown object
// and use data from the other two
// instances to set its fields
Clown clown3 = new Clown();
clown3.Name = anotherClown.Name;
clown3.Height = oneClown.Height - 3;
clown3.WhoAreYou();
```

```
// Notice how there's no "new" statement
// here -- we're not creating a new object,
// just modifying one already in memory
anotherClown.Height *= 2;
anotherClown.WhoAreYou();
```

This object is an instance of the Clown class.



Sometimes code can be difficult to read

You may not realize it, but you're constantly making choices about how to structure your code. Do you use one method to do something? Do you split it into more than one? Do you even need a new method at all? The choices you make about methods can make your code much more intuitive—or if you're not careful, much more convoluted.

Here's a nice, compact chunk of code from a control program that runs a machine that makes candy bars:

```
int t = m.chkTemp();
if (t > 160) {
    T tb = new T();
    tb.clsTrpV(2);
    ics.Fill();
    ics.Vent();
    m.airsyschk();
}
```

Extremely compact code can be especially problematic

Take a second and look at that code. Can you figure out what it does? Don't feel bad if you can't—it's very difficult to read! Here are a few reasons why:

- ★ We can see a few variable names: **tb**, **ics**, **m**. These are terrible names! We have no idea what they do. And what's that **T** class for?
- ★ The `chkTemp` method returns an integer...but what does it do? We can guess maybe it has something to do with checking the temperature of...something?
- ★ The `clsTrpV` method has one parameter. Do we know what that parameter is supposed to be? Why is it 2? What is that 160 number for?



*C# code in **industrial equipment**?! Isn't C# just for desktop apps, business systems, websites, and games?*

C# and .NET are everywhere...and we mean everywhere.

Have you ever played with a Raspberry PI? It's a low-cost computer on a single board, and computers like it can be found inside all sorts of machinery. Thanks to Windows IoT (or Internet of Things), your C# code can run on them.

You can learn more about .NET IoT apps here: <https://dotnet.microsoft.com/apps/iot>

Microsoft even has a free Raspberry PI simulator that you can use to get started:

<https://learn.microsoft.com/azure/iot-hub/iot-hub-raspberry-pi-web-simulator-get-started>

Most code doesn't come with a manual

Those statements don't give you any hints about why the code's doing what it's doing. In this case, the programmer was happy with the results because she was able to get it all into one method. But making your code as compact as possible isn't really useful! Let's break it up into methods to make it easier to read, and make sure the classes are given names that make sense.

We'll start by figuring out what the code is supposed to do. Luckily, we happen to know that this code is part of an **embedded system**, or a controller that's part of a larger electrical or mechanical system. And we happen to have documentation for this code—specifically, the manual that the programmers used when they originally built the system.

General Electronics Type 5 Candy Bar Maker Manual

The nougat temperature must be checked every 3 minutes by an automated system. If the temperature **exceeds 160°C**, the candy is too hot, and the system must **perform the candy isolation cooling system (CICS) vent procedure**:

- Close the trip throttle valve on turbine #2.
- Fill the isolation cooling system with a solid stream of water.
- Vent the water.
- Initiate the automated check for air in the system.

How do you figure out what your code is supposed to do? Well, all code is written for a reason. So it's up to you to figure out that reason! In this case, we got lucky—we could look up the page in the manual that the developer followed.



We can compare the code with the manual that tells us what the code is supposed to do. Adding comments can definitely help us understand what it's supposed to do:

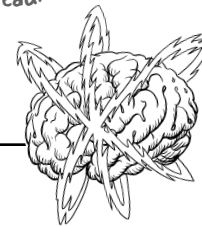
```
/* This code runs every 3 minutes to check the temperature.
 * If it exceeds 160C we need to vent the cooling system.
 */
int t = m.chkTemp();
if (t > 160) {
    // Get the controller system for the turbines
    T tb = new TC();

    // Close throttle valve on turbine #2
    tb.clsTrpV(2);

    // Fill and vent the isolation cooling system
    ics.Fill();
    ics.Vent();

    // Initiate the air system check
    m.airsyschk();
}
```

Adding extra line breaks to your code in some places can make it easier to read.



Brain Power

Code comments are a good start. Can you think of a way to make this code even easier to understand?

Use intuitive class and method names

That page from the manual made it a lot easier to understand the code. It also gave us some great hints about how to make our code easier to understand. Let's take a look at the first two lines:

```
/* This code runs every 3 minutes to check the temperature.
 * If it exceeds 160C we need to vent the cooling system.
 */
int t = m.chkTemp();
if (t > 160) {
```

The comment we added explains a lot. Now we know why the conditional test checks the variable `t` against 160—the manual says that any temperature above 160°C means the nougat is too hot. It turns out that `m` is a class that controls the candy maker, with static methods to check the nougat temperature and check the air system.

So let's put the temperature check into a method, and choose names for the class and the methods that make their purpose obvious. We'll move these first two lines into their own method that returns a Boolean value, true if the nougat is too hot or false if it's OK:

```
/// <summary>
/// If the nougat temperature exceeds 160C it's too hot.
/// </summary>
public bool IsNougatTooHot() {
    int temp = CandyBarMaker.CheckNougatTemperature();
    if (temp > 160) {
        return true;
    } else {
        return false;
    }
}
```

Notice how the C in CandyBarMaker is uppercase? If we always start class names with an uppercase letter and variables with lowercase ones, it's easier to tell when you're calling a static method vs. using an instance.

When we rename the class "CandyBarMaker" and the method "CheckNougatTemperature," it starts to make the code easier to understand.

Did you notice the special `///` comments above the method? That's called an **XML Documentation Comment** (or **XMLDoc**) The IDE uses those comments to show you documentation for methods—like the documentation you saw when you used the IntelliSense window to figure out which method from the Random class to use.



IDE Tip: XML documentation for methods and fields

Visual Studio helps you add XML documentation. Put your cursor in the line above any method and type three slashes, and it will add an empty template for your documentation. If your method has parameters and a return type, it will add `<param>` and `<returns>` tags for them as well. Try going back to your CardPicker class and typing `///` in the line above the PickSomeCards method—the IDE will add blank XML documentation. Fill it in and watch it show up in IntelliSense.

```
/// <summary>
/// Picks a number of cards and returns them.
/// </summary>
/// <param name="numberOfCards">The number of cards to pick.</param>
/// <returns>An array of strings that contain the card names.</returns>
```

You can create XML documentation for your fields too. Try it out by going to the line just above any field and typing three slashes in the IDE. Anything you put after `<summary>` will show up in the IntelliSense window for the field.

What does the manual say to do if the nougat is too hot? It tells us to perform the candy isolation cooling system (or CICS) vent procedure. So let's make another method, and choose an obvious name for the T class (which turns out to control the turbine) and the ics class (which controls the isolation cooling system, and has two static methods to fill and vent the system), and cap it all off with some brief XML documentation:

```

/// <summary>
/// Perform the Candy Isolation Cooling System (CICS) vent procedure.
/// </summary>
public void DoCICSVentProcedure() {
    TurbineController turbines = new TurbineController();
    turbines.CloseTripValve(2);
    IsolationCoolingSystem.Fill();
    IsolationCoolingSystem.Vent();
    Maker.CheckAirSystem();
}

```

When your method is declared with a void return type, that means it doesn't return a value and it doesn't need a return statement. All of the methods you wrote in Chapter 2 used the void keyword!

Now that we have the IsNougatTooHot and DoCICSVentProcedure methods, we can **rewrite the original confusing code as a single method**—and we can give it a name that makes clear exactly what it does:

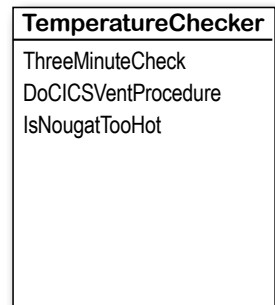
```

/// <summary>
/// This code runs every 3 minutes to check the temperature.
/// If it exceeds 160C we need to vent the cooling system.
/// </summary>
public void ThreeMinuteCheck() {
    if (IsNougatTooHot() == true) {
        DoCICSVentProcedure();
    }
}

```

Now the code is a lot more intuitive! Even if you don't know that the CICS vent procedure needs to be run if the nougat is too hot, **it's a lot more obvious what this code is doing**.

We bundled these new methods into a class called TemperatureChecker. Here's its class diagram.



Use class diagrams to plan out your classes

A class diagram is a valuable tool for designing your code **BEFORE** you start writing it. Write the name of the class at the top of the diagram. Then write each method in the box at the bottom. Now you can see all of the parts of the class at a glance—and that's your first chance to spot problems that might make your code difficult to use or understand later.



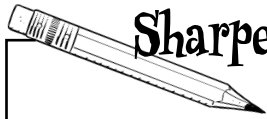
*Hold on, we just did something really interesting!
We just made a lot of changes to a block of code. It looks
really different and it's a lot easier to read now, but **it still does
exactly the same thing.***

That's right. When you change the structure of your code without altering its behavior, it's called refactoring.

Great developers write code that's as easy as possible to understand, even after they haven't looked at it for a long time. Comments can help, but nothing beats choosing intuitive names for your methods, classes, variables, and fields.

You can make your code easier to read and write by thinking about the problem your code was built to solve. If you choose names for your methods that make sense to someone who understands that problem, then your code will be a lot easier to decipher and develop. No matter how well we plan our code, we almost never get things exactly right the first time.

That's why **great developers constantly refactor their code**. They'll move code into methods and give them names that make sense. They'll rename variables. Any time they see code that isn't 100% obvious, they'll take a few minutes to refactor it. They know it's worth taking the time to do it now, because it will make it easier to add more code in an hour (or a day, a month, or a year!).



Sharpen your pencil

Each of these classes has a serious design flaw. Write down what you think is wrong with each class, and how you'd fix it.

Class23
CandyBarWeight
PrintWrapper
GenerateReport
Go

This class is part of the candy manufacturing system from earlier.

.....

.....

.....

.....

DeliveryGuy
AddAPizza
PizzaDelivered
TotalCash
ReturnTime

DeliveryGirl
AddAPizza
PizzaDelivered
TotalCash
ReturnTime

These two classes are part of a system that a pizza parlor uses to track the pizza orders that are out for delivery.

.....

.....

.....

.....

CashRegister
MakeSale
NoSale
PumpGas
Refund
TotalCashInRegister
GetTransactionList
AddCash
RemoveCash

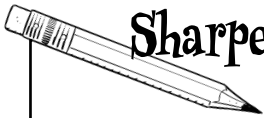
The CashRegister class is part of a program that's used by an automated convenience store checkout system.

.....

.....

.....

.....



Sharpen your pencil Solution

Here's how we improved the classes. We show just one possible way to fix the problems—but there are plenty of other ways you could design these classes depending on how they'll be used.

This class is part of the candy manufacturing system from earlier.

The class name doesn't describe what the class does. A programmer who sees a line of code that calls `Class23.Go` will have no idea what that line does. We'd also rename the method to something that's more descriptive—we chose `MakeTheCandy`, but it could be anything.

CandyMaker
CandyBarWeight
PrintWrapper
GenerateReport
MakeTheCandy

These two classes are part of a system that a pizza parlor uses to track the pizza orders that are out for delivery.

It looks like the `DeliveryGuy` class and the `DeliveryGirl` class both do the same thing—they represent a delivery person who's out delivering pizzas to customers. A better design would replace them with a single class that adds a field for gender.

DeliveryPerson
Gender
AddAPizza
PizzaDelivered
TotalCash
ReturnTime

We decided NOT to add a `Gender` field because there's actually no reason for this pizza delivery class to keep track of the gender of the people delivering pizza—and we should respect their privacy! Always look out for ways that bias can sneak into your code.

The `CashRegister` class is part of a program that's used by an automated convenience store checkout system.

All of the methods in the class do stuff that has to do with a cash register—making a sale, getting a list of transactions, adding cash...except for one: pumping gas. It's a good idea to pull that method out and stick it in another class.

CashRegister
MakeSale
NoSale
Refund
TotalCashInRegister
GetTransactionList
AddCash
RemoveCash



Code Tip: A few ideas for designing intuitive classes

We're about to jump back into writing code. You'll be writing code for the rest of this chapter, and a LOT of code throughout the book. That means you'll be **creating a lot of classes**. Here are a few things to keep in mind when you make choices about how to design them:

- ★ **You're building your program to solve a problem.**
Spend some time thinking about that problem. Does it break down into pieces easily? How would you explain that problem to someone else? These are good things to think about when designing your classes.
- ★ **What real-world things will your program use?**
A program to help a zookeeper track her animals' feeding schedules might have classes for different kinds of food and types of animals.
- ★ **Use descriptive names for classes and methods.**
Someone should be able to figure out what your classes and methods do just by looking at their names.
- ★ **Look for similarities between classes.**
Sometimes two classes can be combined into one if they're really similar. The candy manufacturing system might have three or four turbines, but there's only one method for closing the trip valve that takes the turbine number as a parameter.

Relax

**It's OK if you get stuck when you're writing code.
In fact, getting stuck can be a good thing!**

Writing code is all about solving problems—and some of them can be tricky! But if you keep a few things in mind, it'll make the code exercises go more smoothly:

- ★ It's easy to get caught up in syntax problems, like missing parentheses or quotes. One missing bracket can cause many build errors.
- ★ It's **much better** to look at the solution than to get frustrated with a problem. When you're frustrated, your brain doesn't like to learn.
- ★ All of the code in this book is tested and definitely works! But it's easy to accidentally type things wrong (like typing a one instead of a lowercase L, or missing a comma or semicolon).
- ★ If your solution just won't build, try downloading it from the GitHub repository for the book—it has working code for everything in the book: <https://github.com/head-first-csharp/fifth-edition>

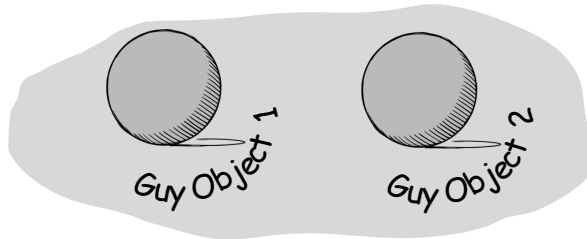
You can learn a lot from reading code. So if you run into a problem with a coding exercise, don't be afraid to peek at the solution. It's not cheating!

Build a class to work with some guys

Joe and Bob lend each other money all the time. Let's create a class to keep track of how much cash they each have. We'll start with an overview of what we'll build.

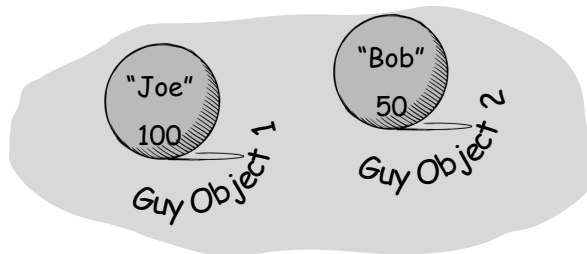
1 We'll create two instances of a "Guy" class.

We'll use two Guy variables called `joe` and `bob` to keep track of each of our instances. Here's what the heap will look like after they're created:

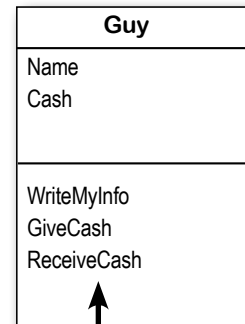


2 We'll set each Guy object's Cash and Name fields.

The two objects represent different guys, each with his own name and a different amount of cash in his pocket. Each guy has a Name field that keeps track of his name, and a Cash field that has the number of bucks in his pocket.



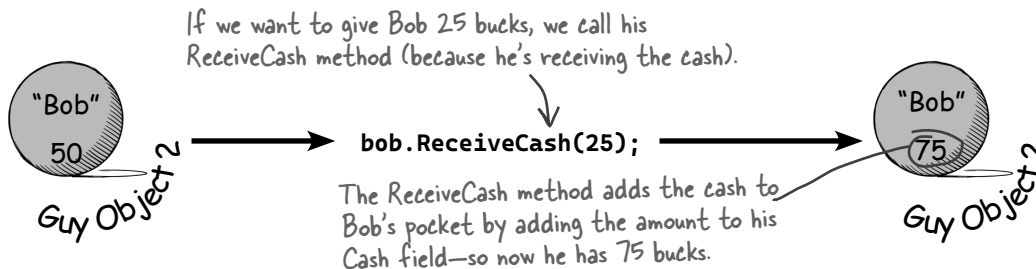
A guy keeps cash ("bucks") in his wallet so he can spend it on stuff. He can give cash to another guy, or receive cash from another guy.



We chose names for the methods that make sense. You call a Guy object's GiveCash method to make him give up some of his cash, and his ReceiveCash method when you want to give cash to him (so he receives it).

3 We'll add methods to give and receive cash.

We'll make a guy give cash from his pocket (and reduce his Cash field) by calling his GiveCash method, which will return the amount of cash he gave. We'll make him receive cash and add it to his pocket (increasing his Cash field) by calling his ReceiveCash method.



```

internal class Guy
{
    public string? Name;
    public int Cash;

    /// <summary>
    /// Writes my name and the amount of cash I have to the console.
    /// </summary>
    public void WriteMyInfo()
    {
        Console.WriteLine(Name + " has " + Cash + " bucks.");
    }

    /// <summary>
    /// Gives some of my cash, removing it from my wallet (or printing
    /// a message to the console if I don't have enough cash).
    /// </summary>
    /// <param name="amount">Amount of cash to give.</param>
    /// <returns>
    /// The amount of cash removed from my wallet, or 0 if I don't
    /// have enough cash (or if the amount is invalid).
    /// </returns>
    public int GiveCash(int amount)
    {
        if (amount <= 0)
        {
            Console.WriteLine(Name + " says: " + amount + " isn't a valid amount");
            return 0;
        }
        if (amount > Cash)
        {
            Console.WriteLine(Name + " says: " +
                "I don't have enough cash to give you " + amount);
            return 0;
        }
        Cash -= amount;
        return amount;
    }

    /// <summary>
    /// Receive some cash, adding it to my wallet (or printing
    /// a message to the console if the amount is invalid).
    /// </summary>
    /// <param name="amount">Amount of cash to receive.</param>
    public void ReceiveCash(int amount)
    {
        if (amount <= 0)
        {
            Console.WriteLine(Name + " says: " + amount + " isn't an amount I'll take");
        }
        else
        {
            Cash += amount;
        }
    }
}

```

The Name and Cash fields keep track of the guy's name and how much cash he has in his pocket. Don't forget the question mark when you declare the `string?` field. We'll talk more about what that's about in the next chapter.

Sometimes you want to ask an object to perform a task, like printing a description of itself to the console.

Don't add this Guy class to an app yet—just read it. Can you figure out how it works?

The GiveCash and ReceiveCash methods verify that the amount they're being asked to give or receive is valid. That way you can't ask a guy to receive a negative number, which would cause him to lose cash.

Compare the comments in this code to the class diagrams and illustrations of the Guy objects. If something doesn't make sense at first, take the time to really understand it.

There's an easier way to initialize objects with C#

Almost every object that you create needs to be initialized in some way. The `Guy` object is no exception—it's useless until you set its `Name` and `Cash` fields. It's so common to have to initialize fields that C# gives you a shortcut for doing that. It's called an **object initializer**, and the IDE's IntelliSense will help you add one.

You're about to do an exercise where you create two `Guy` objects. You *could* use one `new` statement and two more statements to set its fields:

```
joe = new Guy();
joe.Name = "Joe";
joe.Cash = 50;
```

Instead, type this: `Guy joe = new Guy() {`

As soon as you add the left curly bracket, the IDE will pop up an IntelliSense window that shows all of the fields that you can initialize:

```
Guy joe = new Guy() { } ~
  Cash (field) int Guy.Cash
  Name
```

Choose the `Cash` field, set it to 50, and add a comma:

```
Guy joe = new Guy() { Cash = 50,
```

Now type a space—another IntelliSense window will pop up with the remaining field to set:

```
Guy joe = new Guy() { Cash = 50, } ~
  Name (field) string? Guy.Name
```

Set the `Name` field and add the semicolon. You now have a single statement that initializes your object:

```
Guy joe = new Guy() { Cash = 50, Name = "Joe" }; ← This new declaration does the same thing as the three lines of code at the top of the page, but it's shorter and easier to read.
```

Now you have all of the pieces to build your console app that uses two instances of the `Guy` class. Here's what it will look like when it's running: →

Here's how it works. It calls each `Guy` object's `WriteMyInfo` method. It reads an amount from the input and asks who to give the cash to, then calls one `Guy` object's `GiveCash` method, then the other `Guy` object's `ReceiveCash` method. It keeps going until the user enters a blank line, then it calls `return` to exit the app.

Object initializers save you time and make your code more compact and easier to read...and the IDE helps you write them.

```
C:\Users\Public\source x + - □ ×
Joe has 50 bucks.
Bob has 100 bucks.
Enter an amount: 37
Who should give the cash: Bob
Joe has 87 bucks.
Bob has 63 bucks.
Enter an amount:
```

Exercise This is Part 1 of a two-part exercise.

Here are the top-level statements for a console app that makes Guy objects give cash to each other.

Step 1: **Create a new console app** that *uses top-level statements*. Name it Guys.

Step 2: Add a new class to your app called Guy. Since your project is called Guys, your new class will be in the namespace Guys. Carefully **add all of the code from the Guy class** that we just showed you.

Step 3: Here's the code that goes into your app's *Program.cs* file. Carefully enter it, then **replace the comments in with code**—read each comment and write code that does exactly what it says. When you're done, you'll have a program that looks like the screenshot on the previous page.

```
// Create a new Guy object in a variable called joe
// Set its Name field to "Joe"
// Set its Cash field to 50

// Create a new Guy object in a variable called bob
// Set its Name field to "Bob"
// Set its Cash field to 100

while (true)
{
    // Call the WriteMyInfo methods for each Guy object

    Console.Write("Enter an amount: ");
    string? howMuch = Console.ReadLine();
    if (howMuch == "") return;
    // Use int.TryParse to try to convert the howMuch string? to an int
    // if it was successful (just like you did earlier in the chapter)
    {
        Console.Write("Who should give the cash: ");
        string? whichGuy = Console.ReadLine();
        if (whichGuy == "Joe")
        {
            // Call the joe object's GiveCash method and save the results
            // Call the bob object's ReceiveCash method with the saved results
        }
        else if (whichGuy == "Bob")
        {
            // Call the bob object's GiveCash method and save the results
            // Call the joe object's ReceiveCash method with the saved results
        }
        else
        {
            Console.WriteLine("Please enter 'Joe' or 'Bob'");
        }
    }
    else
    {
        Console.WriteLine("Please enter an amount (or a blank line to exit).");
    }
}
}
```

← Replace all of the
comments with code
that does what the
comments describe.

Add another if statement
after an else to check for
more than one condition. This
first checks if whichGuy is Joe,
then it checks if whichGuy is
Bob, and if neither are true, it
writes a line to the console.

Exercise Solution

Here are the top-level statements for your console app. It uses an infinite loop to keep asking the user how much cash to move between the Guy objects. If the user enters a blank line for an amount, the method executes a `return` statement, which causes `Main` to exit and the program to end.

```
using Guys;

(Guy joe = new Guy() ...
Guy joe = new Guy() { Cash = 50, Name = "Joe" };
Guy bob = new Guy() { Cash = 100, Name = "Bob" };

while (true)
{
    joe.WriteMyInfo();
    bob.WriteMyInfo();
    Console.WriteLine("Enter an amount: ");
    string? howMuch = Console.ReadLine();
    if (howMuch == "") return;
    if (int.TryParse(howMuch, out int amount))
    {
        Console.WriteLine("Who should give the cash: ");
        string? whichGuy = Console.ReadLine();
        if (whichGuy == "Joe")
        {
            int cashGiven = joe.GiveCash(amount);
            bob.ReceiveCash(cashGiven);
        }
        else if (whichGuy == "Bob")
        {
            int cashGiven = bob.GiveCash(amount);
            joe.ReceiveCash(cashGiven);
        }
        else
        {
            Console.WriteLine("Please enter 'Joe' or 'Bob'");
        }
    }
    else
    {
        Console.WriteLine("Please enter an amount (or a blank line to exit).");
    }
}
```

When the app executes this `return` statement it ends the program, because console apps stop when the top-level statements finish running.

Here's the code where one Guy object gives cash from his pocket, and the other Guy object receives it.

Use the debugger to step through the code. Put breakpoints in the `if`, `else if`, and `else` blocks. Can you make it hit all three breakpoints?

Don't move on to the next part of the exercise until you have the first part working and you understand what's going on. It's worth taking a few minutes to use the debugger to step through the program and make sure you really get it.

Exercise

Here's the second part of the two-part exercise.

Now that you have your `Guy` class working, let's see if you can **reuse it in a betting game**. Look closely at this screenshot to see how it works and what it prints to the console.

```

Microsoft Visual Studio D x + v - □ ×
Welcome to the casino. The odds are 0.75
The player has 100 bucks.
How much do you want to bet: 36
Bad luck, you lose.
The player has 64 bucks.
How much do you want to bet: 27
You win 54
The player has 91 bucks.
How much do you want to bet: 83
Bad luck, you lose.
The player has 8 bucks.
How much do you want to bet: 8
Bad luck, you lose.
The house always wins.
  
```

These are the odds to beat.

The player makes a double-or-nothing bet each round.

The program picks a random double from 0 to 1. If the number is greater than the odds, the player wins twice their bet, otherwise the player loses.

Create a new console app that uses top-level statements, then add the `Guy` class from your `Guys` project. Make sure you **add a `using` statement to the top of your `Program.cs` file** so you can use the `Guy` class.

In your `Program.cs`, declare two variables:

- A double variable called **odds** that stores the odds to beat set to `.75`
- A `Guy` variable called **player** for an instance of `Guy` named "The player" with 100 bucks.

Your app should write a line to the console welcoming the player and printing the odds. Then it should run this loop:

1. Call the `Guy` object's `WriteMyInfo` method to write the amount of cash the player has to the console.
2. Write a line to the console asking the player how much money to bet.
3. Read the line from the console into a string variable called `howMuch`.
4. Try to parse it into an `int` variable called **amount**.
5. If it parses, the player gives the amount to an `int` variable called `pot`. Only do steps 6 through 9 if `pot` is greater than zero.
6. Multiply `pot` by two, because it's a double-or-nothing bet.
7. Use `Random.Shared` to pick a random double value between 0 and 1.
8. If the random value is greater than `odds`, the player receives the `pot`.
9. If not, the player loses the amount they bet.
10. The program keeps running while the player has cash.

In step 5, you'll call the `Guy` object's `GiveCash` method to give the amount to bet. The `GiveCash` method won't give more cash than the guy has, so you don't need to check if the player has enough money. The `Guy` class will write a message to the console if it doesn't have enough cash to place the bet, so your app doesn't have to. Checking if the `pot` variable is greater than zero makes sure the bet is valid and the player has enough cash.

The loop ends when the player runs out of money, then the app prints a message: "The house always wins."

Exercise Solution

Here's the working code for the top-level statements in the betting game. Can you think of ways to make it more fun? See if you can figure out how to add additional players, or give different options for odds, or maybe you can think of something more clever. ***This is a chance to get creative!***

```
using Guys;

double odds = .75;

Guy player = new Guy() { Cash = 100, Name = "The player" };

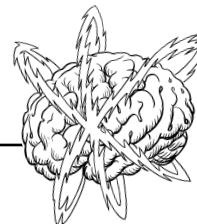
Console.WriteLine("Welcome to the casino. The odds are " + odds);
while (player.Cash > 0)
{
    player.WriteMyInfo();
    Console.WriteLine("How much do you want to bet: ");
    string? howMuch = Console.ReadLine();
    if (int.TryParse(howMuch, out int amount))
    {
        int pot = player.GiveCash(amount) * 2;
        if (pot > 0)
        {
            if (Random.Shared.NextDouble() > odds)
            {
                int winnings = pot;
                Console.WriteLine("You win " + winnings);
                player.ReceiveCash(winnings);
            } else
            {
                Console.WriteLine("Bad luck, you lose.");
            }
        }
    } else
    {
        Console.WriteLine("Please enter a valid number.");
    }
}
Console.WriteLine("The house always wins.");
```

...and to get some practice. Getting practice writing code is the best way to become a great developer.

Was your code a little different than ours? If it still works and produces the right output, that's OK! There are many different ways to write the same program.

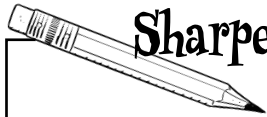
↑

...and as you get further along in the book and the exercise solutions get longer, your code will look more and more different from ours. Remember, it's always OK to look at our solution when you're working on an exercise!



Brain Power

Is Guy really the best name for the class? Why or why not? Can you think of a better name for it?



Sharpen your pencil

Here's an app that writes three lines to the console. Your job is to figure out what it writes, without using a computer. Start at the first line of the Main method and keep track of the values of each of the fields in the objects as it runs.

```
Pizzazz foxtrot = new Pizzazz() { Zippo = 2 };
foxtrot.Bamboo(foxtrot.Zippo);

Pizzazz november = new Pizzazz() { Zippo = 3 };
Abracadabra tango = new Abracadabra() { Vavavoom = 4 };

while (tango.Lala(november.Zippo))
{
    november.Zippo -= 1;
    november.Bamboo(tango.Vavavoom);
    foxtrot.Bamboo(november.Zippo);
    tango.Vavavoom -= foxtrot.Zippo;
}

Console.WriteLine("november.Zippo = " + november.Zippo);
Console.WriteLine("foxtrot.Zippo = " + foxtrot.Zippo);
Console.WriteLine("tango.Vavavoom = " + tango.Vavavoom);
class Pizzazz
{
    public int Zippo;

    public void Bamboo(int eek)
    {
        Zippo += eek;
    }
}

class Abracadabra
{
    public int Vavavoom;

    public bool Lala(int floq)
    {
        if (floq < Vavavoom)
        {
            Vavavoom += floq;
            return true;
        }
        return false;
    }
}
```

What does this program write to the console?

november.Zippo =

foxtrot.Zippo =

tango.Vavavoom =

To find the solution, enter the program into Visual Studio and run it. If you didn't get the answer right, step through the code line by line and add watches for each of the object's fields.

If you don't want to type the whole thing in, you can download it from GitHub: <https://github.com/head-first-csharp/fifth-edition>

Try this a few times with each chatbot.
Does it generate the same code each time?



Ask an AI chatbot to do the exercise to write the betting game code for you

AI chatbots like Copilot, ChatGPT, Gemini, and Claude can do more than answer questions. They can draw pictures, search for information, and even **generate code for you**. Let's use the betting game to explore how this works.

Step 1: Download the PDF of the first four chapters of this book.

We made the first four chapters of this book available as a free PDF. Download it from our GitHub page:

<https://github.com/head-first-csharp/fifth-edition>

Step 2: Use the complete text of Part 1 of the exercise as a prompt.

Open the PDF and find Part 1 of the two-part exercise in this chapter. Part 1 starts with this sentence:

Here are the top-level statements for a console app that makes Guy objects give cash to each other.

Select all of the text for Part 1—including all of the code—starting with “Here are the top-level statements” and ending with the closing bracket } at the bottom.

Open Copilot (<https://copilot.microsoft.com>), ChatGPT (<https://chat.openai.com>), Gemini (<https://gemini.google.com>), Claude (<https://claude.ai>), or any other AI chatbot. Paste in all of the text that you copied as a prompt. The chatbot should generate code for a Guy class, and code for the top-level statements that use it.

Step 3: Create a new Console App project and paste the generated code into it.

Create a new project to test out the code that the AI chatbot generated for you. Create a Guy class in your project, then copy the code that the AI generated for its Guy class and paste it in. Finally, copy the code that the AI generated for its top-level statements into your *Program.cs*.

Step 4: Use the AI safely—trust but verify.

Take the time to understand the code that the AI generated. Try this a few times and compare the results. That's a really good way to learn.



Before you run your app, look at the code. Does it look right?

When we did this ourselves, all three AI chatbots generated working code that did exactly what we asked it to do. However, one of the chatbots ignored our instruction to generate top-level statements and created a console app with a Main method. The app still worked, though!

Also, two of the chatbots used object initializers, while one of them set the fields directly. Our instructions didn't tell it exactly what to do, and either of those choices will work just fine.

Step 5: Finish the betting game.

Find Part 2 of the exercise in the PDF, copy all of the text, and paste it into the chatbot **as a follow-up prompt** (so don't start a new chat). Copy the code that it generates and paste it into your *Program.cs* file. Before you run your app, **carefully read all of the code**. Does it look like it works? Did the AI do things differently than you did?

When we pasted our Part 2 prompt, the betting game worked perfectly. All three chatbots were even smart enough to ignore the instruction in Part 2 to look closely at the screenshot to see how the game works and what it prints to the console, even though we didn't actually include the contents of the screenshot in our prompt.

Did the AI generate code that behaves the same way as the code you wrote for the exercise, but is structured differently? Compare its code to yours—that might give you ideas about how you can refactor your code.



If an AI chatbot is smart enough to write code for me, why should I **bother writing code**? Why should anyone even learn to code in the first place?

It's often *easier to write the code that you want than it is to engineer a prompt to generate that code.*

Creating a prompt isn't always easy. In fact, there's an entire growing field of study called **prompt engineering** that's all about designing prompts to get an AI to do what you want it to do.

Creating a great prompt can include many steps. You need to test the specific language that you're using, examine the output, then refine it to get the AI to give you the output that you're looking for. Prompt engineering can be a difficult and often tedious process, because a very small change in a prompt can make a huge difference in the output that the AI generates.

We know this because ***every coding exercise in this book is a prompt***. The only difference is that instead of building those prompts for an artificial intelligence, we built them to be used by a real, smart, *human* intelligence—namely, *you!*

Every single exercise in this book went through a painstaking process to make sure you have all of the information that you need to do it. When we're building an exercise, we start by writing the code for the solution. Believe it or not, that's the quickest part of creating the exercise. Then we go through a process of creating instructions. We usually have to go through many versions of each exercise before we end up with the version that you see. It's a time-consuming and painstaking process—and sometimes we don't get it right. We got feedback from readers of the first four editions of this book (especially the early editions) who had trouble doing exercises because our instructions were unclear, difficult to follow, and on a few occasions, even missed some steps.

In every single case, writing the code for each exercise was *much* easier than the prompt engineering that we had to do to craft the finished exercise.

In this edition, we tested our exercises by pasting them into different AI chatbots to make sure we didn't accidentally leave out any instructions. If the AI can generate code for a correct solution, it means we included everything you need to do it too.

Exercise

Decide for yourself if prompt engineering is harder than writing code. We gave you this method earlier in the chapter:

```
int Multiply(int factor1, int factor2)
{
    int product = factor1 * factor2;
    return product;
}
```

On our first try, we had to ask four follow-up questions before we could get ChatGPT to give us exactly this output.

Start a new session with an AI chatbot and give it a prompt to create exactly this method. Make sure it doesn't include comments or any additional code. Ask it follow-up questions until it gives you exactly this output.

Repeat the same exercise with the loop from the Sens-AI element in Chapter 2. Can you get the AI to generate it?

Use the C# Interactive window or csi to run C# code

If you just want to run some C# code, you don't always need to create a new project in Visual Studio. Any C# code entered into the **C# Interactive window** is run immediately. You can open it by choosing View >> Other Windows >> C# Interactive. Try it now, and **paste in the code** from the exercise solution to see the output. You can call methods and enter other statements too.

If you're running Windows, open Developer Command Prompt or Developer PowerShell from the Start menu to make sure csi is in your path.

```

C# Interactive
public bool Lala(int floq)
{
    if (floq < Vavavoom)
    {
        Vavavoom += floq;
        return true;
    }
    return false;
}
november.Zippo = 4
foxtrot.Zippo = 8
tango.Vavavoom = -1
> |

Andrews-MBP ~ % csi
Microsoft (R) Visual C# Interactive Compiler version 3.9.0-6.
Copyright (C) Microsoft Corporation. All rights reserved.

Type "#help" for more information.
> class Pizzazz
. . . . .
> class Abracadabra
. . . . .
> Pizzazz foxtrot = new Pizzazz() { Zippo = 2 };
> > > > . . . . .
> Console.WriteLine("november.Zippo = " + november.Zippo);
november.Zippo = 4
> Console.WriteLine("foxtrot.Zippo = " + foxtrot.Zippo);
foxtrot.Zippo = 8
> Console.WriteLine("tango.Vavavoom = " + tango.Vavavoom);
tango.Vavavoom = -1
>
    
```

Paste in each class. You'll see periods for each pasted line.

Only the first pasted line is printed, so we pasted each Console.WriteLine statement separately to see the output.

VSCode doesn't have a C# Interactive window, but you can run csi from Terminal to use the dotnet C# interactive compiler.

You can also run an interactive C# session from the command line. On Windows, search the Start menu for **Developer Command Prompt**, start it, and then type **csi**. On macOS or Linux, run **csi** from the Terminal. You can paste the Pizzazz, Abracadabra, and Program classes from the previous exercise directly into the prompt, then paste in the code that you want to run.

Only the first pasted line is printed, so we pasted each Console.WriteLine statement separately to see the output.

Bullet Points

- Use the **new** keyword to create instances of a class. A program can have many instances of the same class.
- Each **instance** has all of the methods from the class and gets its own copies of each of the fields.
- Use the **static** keyword to declare a field or method in a class as static. You don't need an instance of that class to access static methods or fields.
- When a field is **static**, there's only one copy of it shared by all instances. When you include the **static** keyword in a class declaration, all of its members must be static.
- Fields and methods of a class are called its **members**.
- If you remove the **static** keyword from a static field, it becomes an **instance field**.
- When your program creates an object, it lives in a part of the computer's memory called the **heap**.
- Visual Studio helps you add **XML documentation** (or **XMLDoc**) to your fields and methods, and displays it in its IntelliSense window.
- **Class diagrams** help you plan out your classes and make them easier to work with.
- When you change the structure of your code without altering its behavior, it's called **refactoring**. Advanced developers constantly refactor their code.
- **Object initializers** save you time and make your code more compact and easier to read.

4 data, types, objects, and references

Managing your app's data



Data and objects are the building blocks of your apps.

What would your apps be without data? Think about it for a minute. Without data, your programs are...well, it's actually hard to imagine writing code without data. You need **information** from your users, and you use that to look up or produce new information to give back to them. In fact, almost everything you do in programming involves **working with data** in one way or another. In this chapter, you'll learn the ins and outs of C#'s **data types** and **references**, see how to work with data in your program, and even learn a few more things about **objects** (guess what...objects are data too!).

Owen could use our help!

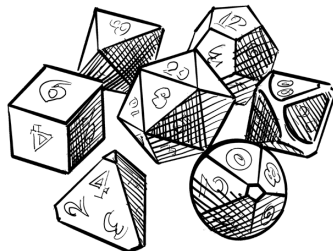
Owen is a game master—a really good one. He hosts a group that meets at his place every week to play different **role-playing games** (or **RPGs**), and like any good game master, he works hard to keep things interesting for the players.



Storytelling, fantasy, and mechanics

Owen is a particularly good storyteller. Over the last few months, he's created an intricate fantasy world for his party, but he's not so happy with the mechanics of the game that they've been playing.

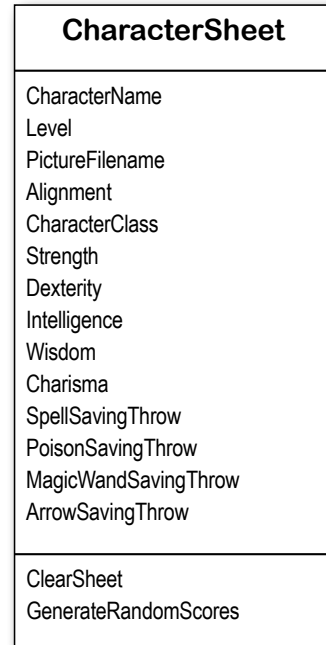
Can we find a way to help Owen improve his RPG?



← Ability score (like strength, stamina, charisma, and intelligence) is an important mechanic in a lot of role-playing games. Players frequently roll dice and use a formula to determine their character's scores.

Character sheets store different types of data on paper

If you've ever played an RPG, you've seen character sheets: a page with details, statistics, background information, and any other notes you might see about a character. If you wanted to make a class to hold a character sheet, what types would you use for the fields?




Character Sheet

ELLIWYNN
Character Name

7
Level

LAWFUL GOOD
Alignment

WIZARD
Character Class



Picture

<div style="border: 1px solid black; padding: 5px; width: 30px; height: 30px; display: flex; align-items: center; justify-content: center;">12</div>	Strength	<input type="radio"/>	Spell Saving Throw
<div style="border: 1px solid black; padding: 5px; width: 30px; height: 30px; display: flex; align-items: center; justify-content: center;">15</div>	Dexterity	<input type="radio"/>	Poison Saving Throw
<div style="border: 1px solid black; padding: 5px; width: 30px; height: 30px; display: flex; align-items: center; justify-content: center;">17</div>	Intelligence	<input checked="" type="radio"/>	Magic Wand Saving Throw
<div style="border: 1px solid black; padding: 5px; width: 30px; height: 30px; display: flex; align-items: center; justify-content: center;">15</div>	Wisdom	<input type="radio"/>	Arrow Saving Throw
<div style="border: 1px solid black; padding: 5px; width: 30px; height: 30px; display: flex; align-items: center; justify-content: center;">10</div>	Charisma	<input type="radio"/>	

This box is for a picture of the character. If you were building a C# class for a character sheet, you could save that picture in an image file.

In the RPG that Owen plays, saving throws give players a chance to roll dice and avoid certain types of attacks. This character has a magic wand saving throw, so the player filled in this circle.

Players create characters by rolling dice for each of their ability scores, which they write in these boxes.



Brain Power

Look at the fields in the CharacterSheet class diagram. What type would you use for each field?

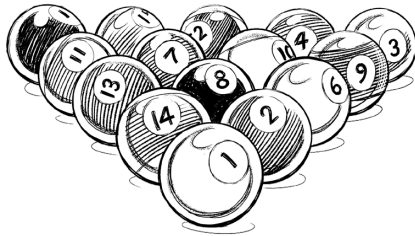
A variable's type determines what kind of data it can store

There are many **types** built into C#, and you'll use them to store many different kinds of data. You've already seen some of the most common ones, like `int`, `string`, `bool`, and `float`. There are a few others that you haven't seen, and they can really come in handy too.

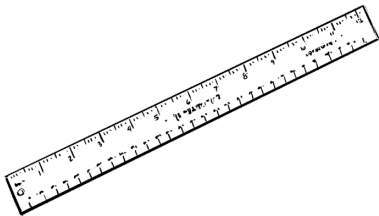
Here are some types you'll use a lot.

**Better a witty fool,
than a foolish wit.**

- ★ **string** can hold text of any length (including the empty string `""`).



- ★ **int** can store any **integer** from $-2,147,483,648$ to $2,147,483,647$. Integers don't have decimal points.



- ★ **float** can store **real** numbers from $\pm 1.5 \times 10^{-45}$ to $\pm 3.4 \times 10^{38}$ with up to 8 significant digits.



- ★ **bool** is a Boolean value—it's either true or false. You'll use it to represent anything that only has two options: it can either be one thing or another, but nothing else.



- ★ **double** can store **real** numbers from $\pm 5.0 \times 10^{-324}$ to $\pm 1.7 \times 10^{308}$ with up to 16 significant digits. It's a really common type when you're working with XAML properties.



**Brain
Power**

Why do you think C# has more than one type for storing numbers that have a decimal point?

C# has several types for storing integers

C# has several different types for integers, as well as `int`. This may seem a little odd (pun intended). Why have so many types for numbers without decimals? For most of the programs in this book, it won't matter if you use an `int` or a `long`. If you're writing a program that has to keep track of millions and millions of integer values, then choosing a smaller integer type like `byte` instead of a bigger type like `long` can save you a lot of memory.


- ★ **`byte`** can store any **integer** between 0 and 255.
- ★ **`sbyte`** can store any **integer** from -128 to 127.
- ★ **`short`** can store any **integer** from -32,768 to 32,767.
- ★ **`long`** can store any **integer** from -9,223,372,036,854,775,808 to 9,223,372,036,854,775,807.

← Notice how we're saying "integer" and not "whole number"? We're trying to be really careful—our high school math teachers always told us that integers are any numbers that can be written without a fraction, while whole numbers are integers starting at 0, and do not include negative numbers.



byte only stores small whole numbers from 0 to 255.


If you need to store a larger number, you can use a `short`, which stores integers from -32,768 to 32,767.



Did you notice that `byte` only stores positive numbers, while `sbyte` stores negative numbers? They both have 256 possible values. The difference is that, like `short` and `long`, `sbyte` can have a negative sign—which is why those are called **signed** types, (the "s" in `sbyte` stands for signed). Just like `byte` is the **unsigned** version of `sbyte`, there are unsigned versions of `short`, `int`, and `long` that start with "u":

- ★ **`ushort`** can store any **whole number** from 0 to 65,535.
- ★ **`uint`** can store any **whole number** from 0 to 4,294,967,295.
- ★ **`ulong`** can store any **whole number** from 0 to 18,446,744,073,709,551,615.

Long also stores integers, but it can store huge values.

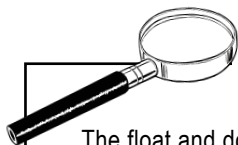


Types for storing really HUGE and really tiny numbers

Sometimes float just isn't precise enough. Believe it or not, sometimes 10^{38} isn't big enough and 10^{-45} isn't small enough. A lot of programs written for finance or scientific research run into these problems all the time, so C# gives us different **floating-point types** to handle huge and tiny values:

- ★ **float** can store any number from $\pm 1.5 \times 10^{-45}$ to $\pm 3.4 \times 10^{38}$ with 6–9 significant digits.
- ★ **double** can store any number from $\pm 5.0 \times 10^{-324}$ to $\pm 1.7 \times 10^{308}$ with 15–17 significant digits.
- ★ **decimal** can store any number from $\pm 1.0 \times 10^{-28}$ to $\pm 7.9 \times 10^{28}$ with 28–29 significant digits. When your program **needs to deal with money or currency**, you always want to use a decimal to store the number.

The decimal type has a lot more precision (way more significant digits), which is why it's appropriate for financial calculations.



Floating-Point Numbers Up Close

The float and double types are called “floating-point” because the decimal point can move (as opposed to a “fixed-point” number, which always has the same number of decimal places). That—and, in fact, a lot of stuff that has to do with floating-point numbers, especially precision—may seem a little **weird**, so let's dig into the explanation.

“Significant digits” represents the precision of the number: 1,048,415, 104.8415, and .0000001048415 all have seven significant digits. So when we say a float can store real numbers as big as 3.4×10^{38} or as small as -1.5×10^{-45} , that means it can store numbers as big as eight digits followed by 30 zeros, or as small as 37 zeros followed by eight digits.

The float and double types can also have special values, including both positive and negative zero, positive and negative infinity, and a special value called **NaN (not-a-number)** that represents, well, a value that isn't a number at all. They also have static methods that let you test for those special values. Try running this loop:

```
for (float f = 10; !float.IsInfinity(f); f *= f)
{
    Console.WriteLine(f);
}
```

Now try that same loop with double:

```
for (double d = 10; !double.IsInfinity(d); d *= d)
{
    Console.WriteLine(d);
}
```

If it's been a while since you've used exponents, 3.4×10^{38} means 34 followed by 37 zeros, and -1.5×10^{-45} is $-.00\dots(40 \text{ more zeros})\dots0015$.

Let's talk about strings

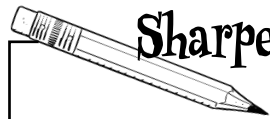
You've written code that works with **strings**. So what, exactly, is a string?

In any .NET app, a string is an object. Its full class name is `System.String`—in other words, the class name is `String` and it's in the `System` namespace (just like the `Random` class you used earlier). When you use the C# **string** keyword, you're working with `System.String` objects. In fact, you can replace **string** with **System.String** in any of the code you've written so far and it will still work! (The **string** keyword is called an *alias*—as far as your C# code is concerned, **string** and **System.String** mean the same thing.)

There are also two special values for strings: an empty string, `""` (or a string with no characters), and a null string, or a string that isn't set to anything at all. We'll talk more about null later in the chapter.

Strings are made up of characters—specifically, Unicode characters (which you'll learn a lot more about later in the book). Sometimes you need to store a single character like `Q` or `j` or `$`, and when you do you'll use the **char** type. Literal values for char are always inside single quotes (`'x'`, `'3'`). You can include **escape sequences** in the quotes too (`'\n'` is a line break, `'\t'` is a tab). You can write an escape sequence in your C# code using two characters, but your program stores each escape sequence as a single character in memory.

And finally, there's one more important type: **object**. If a variable has object as its type, *you can assign any value to it*. The **object** keyword is also an alias—it's the same as `System.Object`.



Sharpen your pencil

Sometimes you declare a variable and set its value in a single statement like this: `int i = 37;`—but you already know that you don't have to set a value. What happens if you use the variable without assigning a value? Let's find out! Use the **C# Interactive window** (or the `csi` if you're using VSCode) to declare a variable and check its value.

We wrote in the first answer for you.

```

..... int i;
..... long l;
..... float f;
..... double d;
..... decimal m;
..... byte b;
..... char c;
..... string s;
..... bool t;

```

```

C# Interactive (64-bit)
Type "#help" for more information.
> int i;
> i
0
> |

```

Start the C# Interactive window (from the View >> Other Windows menu) or run `csi` from the command line. Declare each variable, then enter the variable name to see its default value. Write the default value for each type in the space provided.

```

Macintosh HD — mono --gc-params=nursery-size=64m --clr-memory-model /Library/Frameworks/Mono...
Andrews-MacBook-Pro ~ % csi
Microsoft (R) Visual C# Interactive Compiler version 3.4.0-beta3-19521-01 ()
Copyright (C) Microsoft Corporation. All rights reserved.

Type "#help" for more information.
> int i;
> i
0
> █

```

A literal is a value written directly into your code

A **literal** is a number, string, or other fixed value that you include in your code. You've already used plenty of literals—here are some examples of numbers, strings, and other literals that you've used:

```
int number = 15;
string result = "the answer";
public bool GameOver = false;
Console.WriteLine("Enter the number of cards to pick: ");
if (value == 1) return "Ace";
```

Can you spot all of the literals in these statements from code you've written in previous chapters? The last statement has two literals.

So when you type `int i = 5;`, the `5` is a literal.

Use suffixes to give your literals types

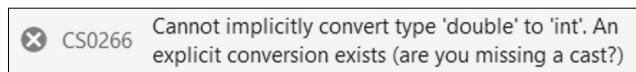
Go back to the first loop you wrote in the “Up Close” section and change `10` to `10D`:

```
for (float f = 10D; float.IsFinite(f); f *= f)
```

Now your *code will have a syntax error and won't build*. The C# compiler error mentions a “literal of type double.” That's because **literals have types**. Every literal is automatically assigned a type, and C# has rules about how you can combine different types. You can see for yourself how that works. Add this line to any C# program:

```
int wholeNumber = 14.7;
```

When you try to build your program, the IDE will show you this error in the Error List:



The IDE is telling you is that the literal `14.7` has a type—it's a double. You can use a suffix to change its type—try changing it to a float by sticking an `F` on the end (`14.7F`) or a decimal by adding `M` (`14.7M`—the `M` actually stands for “money”). The error message now says it can't convert float or decimal.

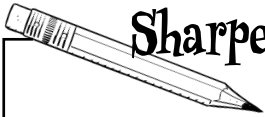
C# assumes that an integer literal without a suffix (like `371`) is an int, and one with a decimal point (like `27.4`) is a double.

Sharpen your pencil Solution

```
..... int i;
..... long l;
..... float f;
..... double d;
```

```
..... decimal m;
..... byte b;
..... char c;
..... string s;
..... bool t;
```

If you used the C# command line on Mac or Linux, you might see `\x0` instead of `\0` as the default value for char. We'll take a deep dive into exactly what this means later in the book when we talk about Unicode.



Sharpen your pencil

C# has dozens of **reserved words called keywords**. They're words reserved by the C# compiler that you can't use for variable names. You've already learned many of them—here's a little review to help seal them into your brain. Write down what you think each of these keywords does in C#.

namespace

for

class

else

new

using

if

while

If you really want to use a reserved keyword as a variable name, put @ in front of it, but that's as close as the compiler will let you get to the reserved word. You can also do that with nonreserved names, if you want to.



Sharpen your pencil Solution

C# has dozens of **reserved words called keywords**. They're words reserved by the C# compiler that you can't use for variable names. You've already learned many of them—here's a little review to help seal them into your brain. Write down what you think each of these keywords does in C#.

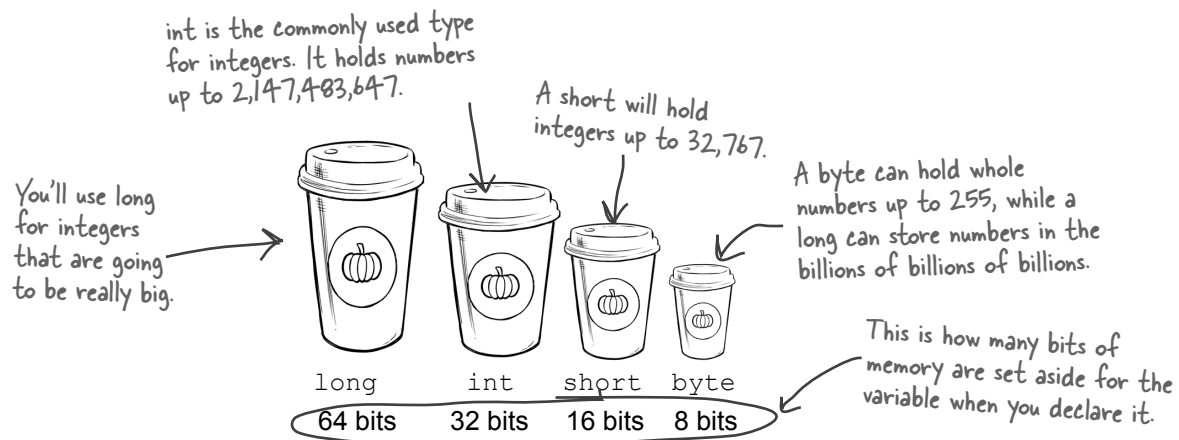
namespace	All of the classes and methods in a program are inside a namespace.
	Namespaces help make sure that the names you are using in your program don't clash with the ones in the .NET Framework or other classes.
for	This lets you do a loop that executes three statements. First it declares the variable it's going to use, then there's the statement that evaluates the variable against a condition. The third statement does something to the value.
class	Classes contain methods and fields, and you use them to instantiate objects. Fields are what objects know and methods are what they do.
else	A block of code that starts with else must immediately follow an if block, and will get executed if the if statement preceding it fails.
new	You use this to create a new instance of an object.
using	This is a way of listing off all of the namespaces you are using in your program. A using statement lets you use classes from various parts of the .NET Framework.
if	This is one way of setting up a conditional statement in a program. It says if one thing is true, do one thing; if not, do something else.
while	while loops are loops that keep on going as long as the condition at the beginning of the loop is true.

A variable is like a data to-go cup

All of your data takes up **space in memory**. (Remember the heap from the previous chapter?) So part of your job is to think about how *much* space you're going to need whenever you use a string or a number in your program. That's one of the reasons you use variables. They let you set aside enough space in memory to store your data.

Think of a variable like a cup that you keep your data in. C# uses a bunch of different kinds of cups to hold different kinds of data. Just like the different sizes of cups at a coffee shop, there are different sizes of variables too.

Not all data ends up on the heap. Value types usually keep their data in another part of memory called the stack. You'll learn all about that later in the book.



Use the Convert class to explore bits and bytes

Convert this!

You've always heard that programming is about 1s and 0s. .NET has a **static Convert class** that converts between different numeric data types. Let's use it to see an example of how bits and bytes work. Type these Convert method calls into the Visual Studio C# Interactive window or CSI.

A bit is a single 1 or 0. A byte is 8 bits, so a byte variable holds an 8-bit number, which means it's a number that can be represented with up to 8 bits. What does that look like? Let's use the Convert class to convert some binary numbers to bytes:

```
Convert.ToByte("10111", 2) // returns 23
Convert.ToByte("11111111", 2) // returns 255
```

The first argument to Convert.ToByte is the number to convert, and the second is its base. Binary numbers are base 2.

Bytes can hold numbers between 0 and 255 because they use 8 bits of memory—an 8-bit number is a binary number between 0 and 11111111 binary (or 0 and 255 decimal).

A short is a 16-bit value. Let's use **Convert.ToInt16** to convert the binary value 1111111111111111 (15 1s) to a short. An int is a 32-bit value, so we'll use **Convert.ToInt32** to convert the 31 1s to an int:

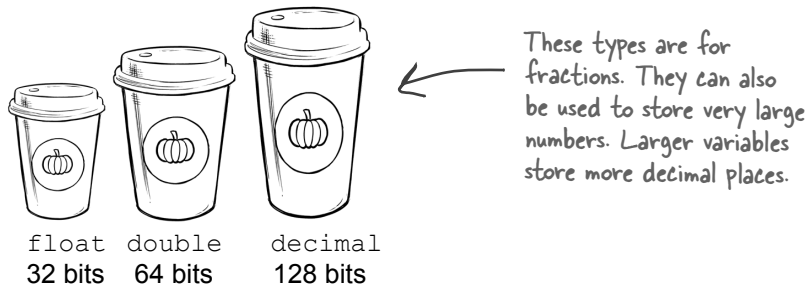
```
Convert.ToInt16("1111111111111111", 2) // returns 32767
Convert.ToInt32("11111111111111111111111111111111", 2) // returns 2147483647
```


bigger types take more memory

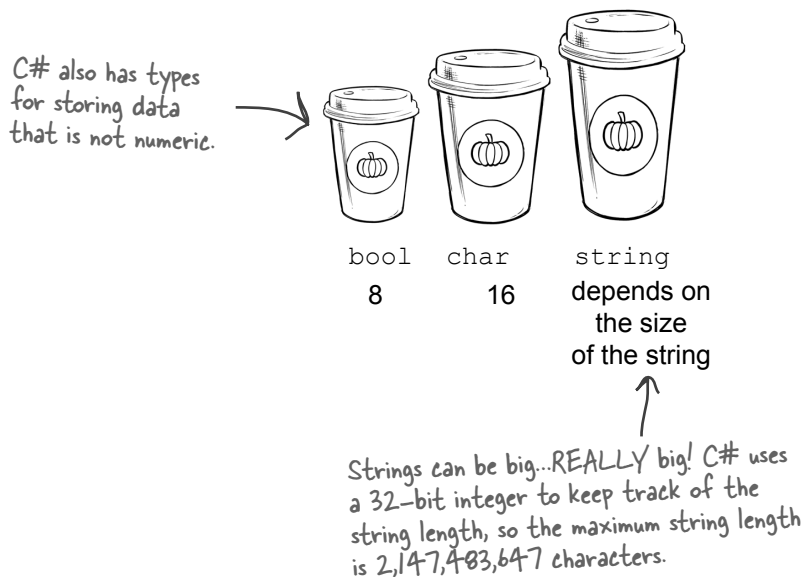
Other types come in different sizes too

Numbers that have decimal places are stored differently than integers, and the different floating-point types take up different amounts of memory. You can handle most of your numbers that have decimal places using **float**, the smallest data type that stores decimals. If you need to be more precise, use a **double**. If you're writing a financial application where you'll be storing currency values, you'll always want to use the **decimal** type.

Oh, and one more thing: **don't use double for money or currency, only use decimal.**

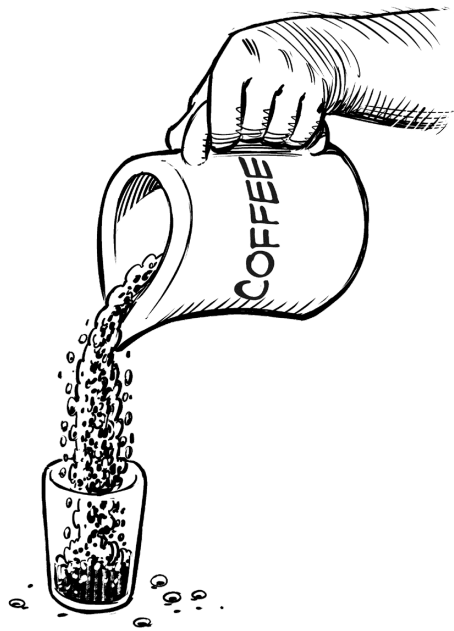


We've talked about strings, so you know that the C# compiler also can handle **characters and non-numeric types**. The **char** type holds one character, and **string** is used for lots of characters "strung" together. There's no set size for a string object—it expands to hold as much data as you need to store in it. The **bool** data type is used to store true or false values, like the ones you've used for your **if** statements.



The different floating-point types take up different amounts of memory: float is smallest, and decimal is largest.

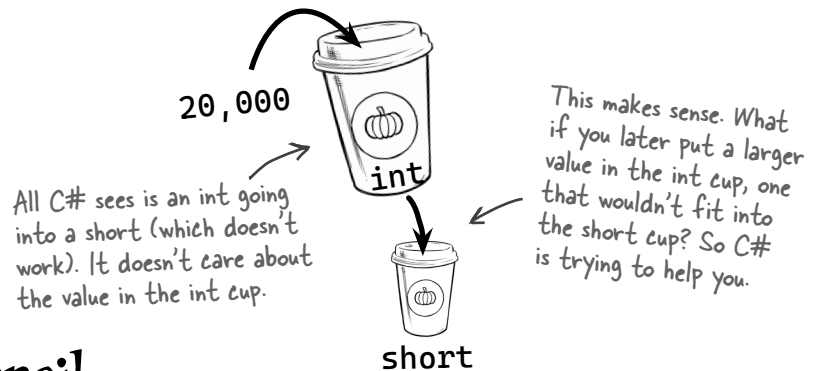
10 pounds of data in a 5-pound bag



When you declare your variable as one type, the C# compiler **allocates** (or reserves) all of the memory it would need to store the maximum value of that type. Even if the value is nowhere near the upper boundary of the type you've declared, the compiler will see the cup it's in, not the number inside. So this won't work:

```
int leaguesUnderTheSea = 20000;
short smallerLeagues = leaguesUnderTheSea;
```

20,000 would fit into a **short**, no problem. But because **leaguesUnderTheSea** is declared as an **int**, C# sees it as int-sized and considers it too big to put in a short container. The compiler won't make those translations for you on the fly. You need to make sure that you're using the right type for the data you're working with.



Sharpen your pencil

Three of these statements won't build, either because they're trying to cram too much data into a small variable or because they're putting the wrong type of data in. Circle them and write a brief explanation of what's wrong.

```
int hours = 24;
```

```
string taunt = "your mother";
```

```
short y = 78000;
```

```
byte days = 365;
```

```
bool isDone = yes;
```

```
int radius = 3;
```

```
short RPM = 33;
```

```
char initial = 'S';
```

```
int balance = 345667 - 567;
```

```
string months = "12";
```

Casting lets you copy values that C# can't automatically convert to another type

Let's see what happens when you try to assign a decimal value to an int variable.

Do this!

- 1 Create a new Console App project and add this code to your *Program.cs*:

```
float myFloatValue = 10;
int myIntValue = myFloatValue;
Console.WriteLine("myIntValue is " + myIntValue);
```

Implicit conversion means C# has a way to automatically convert a value to another type without losing information.

- 2 Try building your program. You should get the same CS0266 error you saw earlier:

```
✘ CS0266 Cannot implicitly convert type 'float' to 'int'. An explicit conversion exists (are you missing a cast?)
```

Look closely at the last few words of the error message: “are you missing a cast?” That’s the C# compiler giving you a really useful hint about how to fix the problem.

- 3 Make the error go away by **casting** the decimal to an int. You do this by adding the type that you want to convert to in parentheses: **(int)**. Once you change the second line so it looks like this, your program will compile and run:

```
int myIntValue = (int) myFloatValue;
```

Here's where you cast the decimal value to an int.

When you cast a floating-point value to an int, it rounds the value down to the nearest integer.

So what happened?

The C# compiler won't let you assign a value to a variable if it's the wrong type—even if that variable can hold the value just fine! It turns out that a LOT of bugs are caused by type problems, and **the compiler is helping** by nudging you in the right direction. When you use casting, you're essentially saying to the compiler that you know the types are different, and promising that in this particular instance it's OK for C# to cram the data into the new variable.

Sharpen your pencil Solution

Three of these statements won't build, either because they're trying to cram too much data into a small variable or because they're putting the wrong type of data in. Circle them and write a brief explanation of what's wrong.

short y = 78000;	The short type holds numbers from -32,767 to 32,768. This number's too big!	byte days = 365;	A byte can only hold a value between 0 and 255. You'll need a short for this.
bool isDone = yes;	You can only assign a value of "true" or "false" to a bool.		

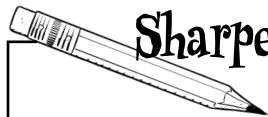
When you cast a value that's too big, C# adjusts it to fit its new container

You've already seen that a float can be cast to an int. It turns out that *any* number can be cast to *any other* number. That doesn't mean the **value** stays intact through the casting, though. Say you have an int variable set to 365. If you cast it to a byte variable (max value 255), instead of giving you an error, the value will just **wrap around**. 256 cast to a byte will have a value of 0, 257 will be converted to 1, 258 to 2, etc., up to 365, which will end up being **109**. Once you get back to 255 again, the conversion value “wraps” back to zero.

If you use + (or *, /, or -) with two different numeric types, the operator **automatically converts** the smaller type to the bigger one. Here's an example:

```
int myInt = 36;
float myFloat = 16.4F;
myFloat = myInt + myFloat;
```

Since an int can fit into a float but a float can't fit into an int, the + operator converts **myInt** to a float before adding it to **myFloat**.



Sharpen your pencil

You can't always cast any type to any other type.

Create a new Console App project and type these statements into its top-level statements. Then build your program—it will give lots of errors. Cross out the ones that give errors. This is a great way to help you figure out which types can be cast, and which can't.

```
int myInt = 10;
byte myByte = (byte)myInt;
double myDouble = (double)myByte;
bool myBool = (bool)myDouble;
string myString = "false";
myBool = (bool)myString;

myString = (string)myInt;
myString = myInt.ToString();
myBool = (bool)myByte;
myByte = (byte)myBool;
short myShort = (short)myInt;
char myChar = 'x';
myString = (string)myChar;
long myLong = (long)myInt;
decimal myDecimal = (decimal)myLong;
myString = myString + myInt + myByte +
myDouble + myChar;
```

You can read a lot more about the different C# value types here—it's worth taking a look:
<https://docs.microsoft.com/dotnet/csharp/language-reference/keywords/value-types>



I've been combining numbers and strings in my message boxes since I worked with loops in Chapter 2! Have I been **converting types** all along?

Yes! When you concatenate strings, C# converts values.

When you use the + operator to combine a string with another value, it's called **concatenation**. When you concatenate a string with an int, bool, float, or another value type, it automatically converts the value. This kind of conversion is different from casting, because under the hood it's really calling the ToString method for the value...and one thing that .NET guarantees is that **every object has a ToString method** that converts it to a string (but it's up to the individual class to determine if that string makes sense).

Wrap it yourself!

There's no mystery to how casting "wraps" the numbers—you can do it yourself. Just open up any calculator app that has a Mod button (which does a modulus calculation—sometimes in a Scientific mode), and calculate $365 \text{ Mod } 256$.

Sharpen your pencil Solution

You can't always cast any type to any other type. Create a new Console App project and type these statements into its top-level statements. Then build your program—it will give lots of errors. Cross out the ones that give errors. This is a great way to help you figure out which types can be cast, and which can't.

```
int myInt = 10;
byte myByte = (byte)myInt;
double myDouble = (double)myByte;
bool myBool = (bool)myDouble;
string myString = "false";
myBool = (bool)myString;
myString = (string)myInt;
myString = myInt.ToString();
myBool = (bool)myByte;
myByte = (byte)myBool;
short myShort = (short)myInt;
char myChar = 'x';
myString = (string)myChar;
long myLong = (long)myInt;
decimal myDecimal = (decimal)myLong;

myString = myString + myInt + myByte + myDouble + myChar;
```

C# does some conversions automatically

There are two important conversions that don't require you to do casting. The first is the automatic conversion that happens any time you use arithmetic operators, like in this example:

```
long l = 139401930;
short s = 516;
double d = l - s;
d = d / 123.456;
Console.WriteLine("The answer is " + d);
```

The `-` operator subtracted the short from the long, and the `=` operator converted the result to a double.

The other way C# converts types for you automatically is when you use the `+` operator to **concatenate** strings (which just means sticking one string on the end of another, like you've been doing with message boxes). When you use `+` to concatenate a string with something that's another type, it automatically converts the numbers to strings for you. Here's an example—try adding these lines to any C# program. The first two lines are fine, but the third one won't compile:

```
long number = 139401930;
string text = "Player score: " + number;
text = number;
```

The C# compiler gives you this error on the third line:

```
✘ CS0029 Cannot implicitly convert type 'long' to 'string'
```

text is a string variable, so when you used the `+` operator to concatenate a string it converted the value to a string and the assignment worked. But when you try to assign the number value to it directly, it doesn't have a way to automatically convert the long value to a string. You can convert a numeric value (or any other value!) to a string by calling its `ToString` method.

there are no Dumb Questions

Q: You used the `Convert.ToByte`, `Convert.ToInt32`, and `Convert.ToInt64` methods to convert strings with binary numbers into integer values. Can you convert integer values back to binary?

A: Yes. The `Convert` class has a **`Convert.ToString`** method that converts many different types of values to strings. The IntelliSense pop-up shows you how it works:

```
Console.WriteLine(Convert.ToString(8675309, 2));
```

```
▲ 26 of 36 ▼ string Convert.ToString(int value, int toBase)
Converts the value of a 32-bit signed integer to its equivalent string representation in a specified base.
toBase: The base of the return value, which must be 2, 8, 10, or 16.
```

So `Convert.ToString(255, 2)` returns the string "11111111," and `Convert.ToString(8675309, 2)` returns the string "10000100010111111101101"—try experimenting with it to get a feel for how binary numbers work.

some conversions are automatic

When you call a method, the arguments need to be compatible with the types of the parameters

In Chapter 3, you used the `Random` class to choose a random number from 1 up to (but not including) 5, which you used to pick a suit for a playing card:

```
int value = Random.Shared.Next(1, 5);
```

Try changing the first argument from `1` to `1.0`:

```
int value = Random.Shared.Next(1.0, 5);
```

You're passing a double literal to a method that's expecting an `int` value. So it shouldn't surprise you that the compiler won't build your program—instead, it shows an error:

```
✘ CS1503 Argument 1: cannot convert from 'double' to 'int'
```

Sometimes C# can do the conversion automatically. It doesn't know how to convert a double to an `int` (like converting 1.0 to 1), but it does know how to convert an `int` to a double (like converting 1 to 1.0). More specifically:

- ★ The C# compiler knows how to convert an integer to a floating-point type.
- ★ And it knows how to convert an integer type to another integer type, or a floating-point type to another floating-point type.
- ★ But it can only do those conversions if the type it's converting from is the same size as or smaller than the type it's converting to. So, it can convert an `int` to a `long` or a `float` to a `double`, but it can't convert a `long` to an `int` or a `double` to a `float`.

But `Random.Shared.Next` isn't the only method that will give you compiler errors if you try to pass it a variable whose type doesn't match the parameter. *All* methods will do that, *even the ones you write yourself*. Add this method to a console app's top-level statements:

```
int MyMethod(bool add3) {  
    int value = 12;  
  
    if (add3)  
        value += 3;  
    else  
        value -= 2;  
  
    return value;  
}
```

Try passing it a string or `long`—you'll get one of those CS1503 errors telling you it can't convert the argument to a `bool`.

Some folks have trouble remembering **the difference between a parameter and an argument**. So just to be clear:

A parameter is what you define in your method. An argument is what you pass to it. You can pass a byte argument to a method with an `int` parameter.

When the compiler gives you an “invalid argument” error, it means that you tried to call a method with variables whose types didn't match the method's parameters.

there are no Dumb Questions

Q: That last `if` statement only said `if (add3)`. Is that the same thing as `if (add3 == true)`?

A: Yes. Let's take another look at that `if/else` statement:

```
if (add3)
    value += 3;
else
    value -= 2;
```

An `if` statement always checks if something's true. So because the type of the `add3` variable is `bool`, it evaluates to either true or false, which means we didn't have to explicitly include `== true`.

You can also check if something's false using `!` (an exclamation point, or the NOT operator). Writing `if (!add3)` is the same thing as writing `if (add3 == false)`.

In our code examples from now on, if we're using the conditional test to check a Boolean variable, you'll usually just see us write `if (add3)` or `if (!add3)`, and not use `==` to explicitly check to see if the Boolean is true or false.

Q: You didn't include curly braces in the `if` or `else` blocks either. Does that mean they're optional?

A: Yes—but only if there's a single statement in the `if` or `else` block. We could leave out the `{ }` curly braces because there was just one statement in the `if` block (`return 45;`) and one statement in the `else` block (`return 61;`). If we wanted to add another statement to one of those blocks, we'd have to use curly braces for it:

```
if (add3)
    value += 3;
else {
    Console.WriteLine("Subtracting 2");
    value -= 2;
}
```

Be careful when you leave out curly braces because it's easy to accidentally write code that doesn't do what you want it to do. It never hurts to add curly braces, but it's also good to get used to seeing `if` statements both with and without them.

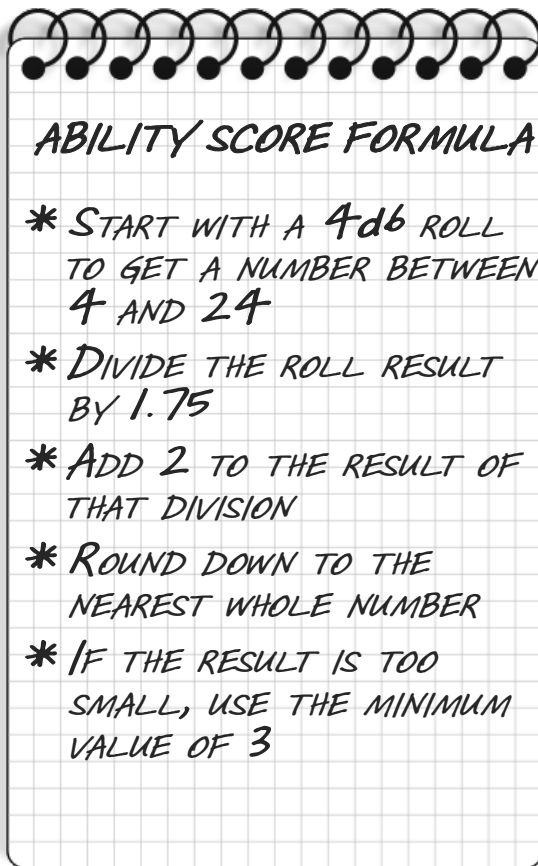
Bullet Points

- There are value types for variables that hold different sizes of numbers. The biggest numbers should be of type `long` and the smallest ones (up to 255) can be declared as `bytes`.
- Every value type has a **size**, and you can't put a value of a bigger type into a smaller variable, no matter what the actual size of the data is.
- When you're using **literal** values, use the `F` suffix to indicate a float (15.6F) and `M` for a decimal (36.12M).
- Use the **decimal type for money and currency**. Floating-point precision is...well, it's a little weird.
- There are a few types that `C#` knows how to **convert** automatically (an implicit conversion), like `short` to `int`, `int` to `double`, or `float` to `double`.
- When the compiler won't let you set a variable equal to a value of a different type, that's when you need to cast it. To **cast** a value (an explicit conversion) to another type, put the target type in parentheses in front of the value.
- Some keywords are **reserved** by the language and you can't name your variables with them. They're words (like `for`, `while`, `using`, `new`, and others) that do specific things in the language.
- A **parameter** is what you define in your method. An **argument** is what you pass to it.
- When you build your code in the IDE, it uses the **C# compiler** to turn it into an executable program.
- You can use methods on the static **Convert class** to convert values between different types.

Owen is constantly improving his game...

Good game masters are dedicated to creating the best experience they can for their players. Owen's players are about to embark on a new campaign with a brand-new set of characters, and he thinks a few tweaks to the formula that they use for their ability scores could make things more interesting.

When players fill out their character sheets at the start of the game, they follow these steps to calculate each of the ability scores for their character.



ABILITY SCORE FORMULA

- * START WITH A 4d6 ROLL TO GET A NUMBER BETWEEN 4 AND 24
- * DIVIDE THE ROLL RESULT BY 1.75
- * ADD 2 TO THE RESULT OF THAT DIVISION
- * ROUND DOWN TO THE NEAREST WHOLE NUMBER
- * IF THE RESULT IS TOO SMALL, USE THE MINIMUM VALUE OF 3

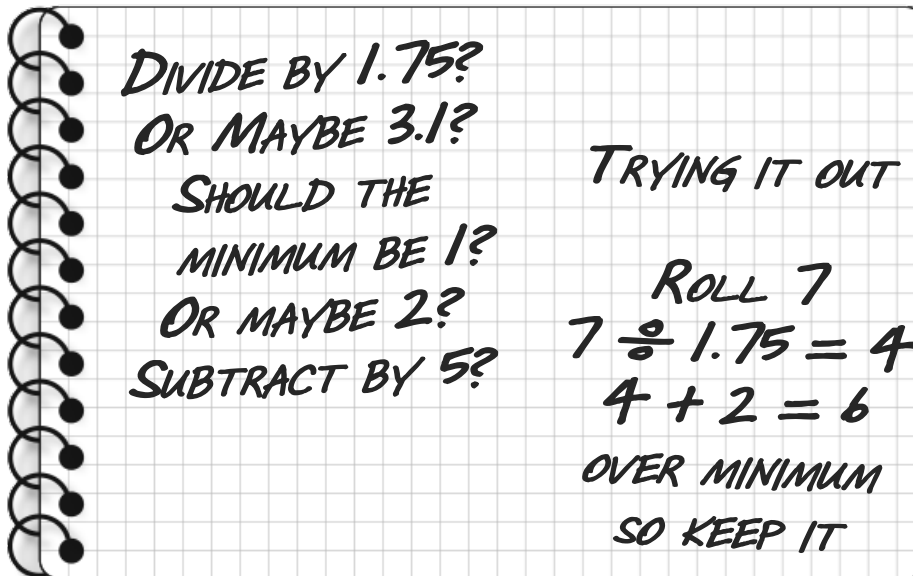
↑
A "4d6 ROLL" means rolling four normal six-sided dice and adding up the results.

The standard rules for this game are a good starting point, but I know we can do better.



...but the trial and error can be time-consuming

Owen's been experimenting with ways to tweak the ability score calculation. He's pretty sure that he has the formula mostly right—but he'd really like to tweak the numbers.



Owen likes the overall formula: 4d6 roll, divide, subtract, round down, use a minimum value...but he's not sure that the actual numbers are right.



I think 1.75 may be a little low to divide the roll result by, and maybe we want to add 3 to the result instead of 4. I bet there's an easier way to test out these ideas!



**Brain
Power**

What can we do to help Owen find the best combination of values for an updated ability score formula?

Let's help Owen experiment with ability scores

In this next project, you'll build a console app that Owen can use to test his ability score formula with different values to see how they affect the resulting score. The formula has **four inputs**: the *starting 4d6 roll*, the *divide by* value that the roll result is divided by, the *add amount* value to add to the result of that division, and the *minimum* to use if the result is too small.

Owen will enter each of the four inputs into the app, and it will calculate the ability score using those inputs. He'll probably want to test a bunch of different values, so we'll make the app easier to use by asking for new values over and over again until he quits the app, keeping track of the values he used in each iteration and using those previous inputs as **default values** for the next iteration.

This is what it looks like when Owen runs the app:

The screenshot shows a terminal window with the following text:

```
C:\Users\Public\source\repos' x + v
Starting 4d6 roll [14]:
  using default value 14
Divide by [1.75]:
  using default value 1.75
Add amount [2]:
  using default value 2
Minimum [3]:
  using default value 3
Calculated ability score: 10
Press Q to quit, any other key to continue
Starting 4d6 roll [14]:
  using default value 14
Divide by [1.75]: 2.15
  using value 2.15
Add amount [2]: 5
  using value 5
Minimum [3]: 2
  using value 2
Calculated ability score: 11
Press Q to quit, any other key to continue
Starting 4d6 roll [14]: 21
  using value 21
Divide by [2.15]:
  using default value 2.15
Add amount [5]:
  using default value 5
Minimum [2]:
  using default value 2
Calculated ability score: 14
Press Q to quit, any other key to continue
```

Handwritten annotations in the terminal:

- A bracket groups the first three prompts: "The app prompts for the various values used to calculate the ability score. It puts a default value like [14] or [1.75] in square brackets. Owen can enter a value, or just hit Enter to accept a default value."
- A bracket groups the second iteration's prompts: "Here Owen is trying out new values: divide the roll result by 2.15 (instead of 1.75), add 5 (instead of 2) to the result of that division, and a minimum value of 2 (instead of 3). With an initial roll of 14, that gives an ability score of 11."
- A bracket groups the third iteration's prompts: "Now Owen wants to check those same values with a different starting 4d6 roll, so he enters 21 as the starting roll, presses Enter to accept the default values that the app remembered from the previous iteration, and gets an ability score of 14."

On the right, a notebook page titled "ABILITY SCORE FORMULA" contains the following list:

- * START WITH A 4d6 ROLL TO GET A NUMBER BETWEEN 4 AND 24
- * DIVIDE THE ROLL RESULT BY 1.75
- * ADD 2 TO THE RESULT OF THAT DIVISION
- * ROUND DOWN TO THE NEAREST WHOLE NUMBER
- * IF THE RESULT IS TOO SMALL, USE THE MINIMUM VALUE OF 3

An arrow points from the text "Here's the page from Owen's game master notebook with the ability score formula." to the notebook page.

This project is a little larger than the previous console apps that you've built, so we'll tackle it in a few steps. First you'll Sharpen your Pencil to understand the code to calculate the ability score. Then you'll do an Exercise to write the rest of the code for the app. And finally, you'll Sleuth out a bug in the code. Let's get started!



Sharpen your pencil

We've built a class to help Owen calculate ability scores. To use it, you'll set its RollResult, DivideBy, AddAmount, and Minimum fields—or just leave the values set in their declarations—and call its CalculateAbilityScore method.

Create a new Console App project called AbilityScore and **add a class called AbilityScoreCalculator**. Enter all of the code into the class file. Uh-oh! There's one line of code that has a problem. **Circle the line of code** that causes a compiler error. Then **write down what you think you'll need to do to fix it**.

```
namespace AbilityScore;
internal class AbilityScoreCalculator
{
    public int RollResult = 14;
    public double DivideBy = 1.75;
    public int AddAmount = 2;
    public int Minimum = 3;
    public int Score;

    public void CalculateAbilityScore()
    {
        // Divide the roll result by the DivideBy field
        double divided = RollResult / DivideBy;

        // Add AddAmount to the result and round down
        int added = AddAmount += divided;

        // If the result is too small, use Minimum
        if (added < Minimum)
        {
            Score = Minimum;
        } else
        {
            Score = added;
        }
    }
}
```

If you're using VSCode, you can replace the "internal" access modifier with "public"—it won't make a difference in how the app works.



These fields are initialized with the values from the ability score formula. The app will use them to present default values to the user.

Here's a hint! Visual Studio will show you which line of code won't compile, and underline the specific part that has problems. Hover over that part and look closely at the error message.



After you **circle the line of code that won't compile**, write down what you need to do to fix the compiler error.

.....

.....

Fix the compiler error by adding a cast



If you entered the code correctly, you should see a C# compiler error on this line of code:

Here's the line of code to circle in the "Sharpen your pencil" exercise.

```
int added = AddAmount += divided;
```

(field) int AbilityScoreCalculator.AddAmount

No examples or documentation available.

This C# compiler error message is giving you a big hint—it looks like we forgot to cast a value.

CS0266: Cannot implicitly convert type 'double' to 'int'. An explicit conversion exists (are you missing a cast?)

Any time the C# compiler gives you an error, read it carefully. It often has a hint that can help you track down the problem. This error tells us exactly what went wrong: **it can't convert a double to an int without a cast**. The `divided` variable is declared as a double, but C# won't allow you to add it to an int field like `AddAmount` because it doesn't know how to convert it. **So here's the answer** to the "Sharpen your pencil" question:

After you **circle the line of code that has problems**, look at the error and write down what you need to do to fix it. The compiler error says it can't convert a double to an int, and asks if our code is missing a cast. To fix it, we need to use `(int)` to cast the double to an int so `+=` will be able to add the values.

When the C# compiler asks "are you missing a cast?" it's giving you a huge hint that you need to **cast the double variable `divided`** before you can add it to the int field `AddAmount`.

Add a cast to get the `AbilityScoreCalculator` class to compile...

But this isn't the whole answer! There's still something wrong with that line of code. Can you spot it?

Now that you know what the problem is, you can **add a cast** to fix the problematic line of code in `AbilityScoreCalculator`. The line that caused the error because **`AddAmount += divided` returns a double value**. When you try to store a double value in an int variable like `added`, you'll get a "Cannot implicitly convert type" error.

You can fix it by **casting `divided` to an int**, so adding it to `AddAmount` returns another int. Modify that line of code to change `divided` to **`(int)divided`**:

```
int added = AddAmount += (int)divided;
```

Cast this!

Adding that cast also *addresses an important part* of Owen's ability score formula:

* *ROUND DOWN TO THE NEAREST WHOLE NUMBER*

When you cast a double to an int, C# rounds it down—so for example `(int)19.7431D` gives us `19`. By adding that cast, you're making sure the score is rounded down, like Owen's formula asks for.

...but there's still a bug!

We're not quite done yet! You fixed the compiler error, so now the project builds. But even though the C# compiler will accept it, **there's still a bug in the code**. So let's go ahead and fix it! In the next exercise, you'll use the `AbilityScoreCalculator` class as is, then you'll use it to sleuth out the bug.

Exercise

Finish building the console app that uses the `AbilityScoreCalculator` class. In this exercise, we'll give you the top-level statements for the console app. Your job is to write code for two methods: a method called `ReadInt` that reads user input and converts it to an int using `int.TryParse`, and a method called `ReadDouble` that does exactly the same thing except it parses doubles instead of int values.

Step 1: In this first step, you'll add top-level statements to your `Program.cs` file. Almost everything was used in previous projects. There's only one new thing—it calls the `Console.ReadKey` method:

```
char keyChar = Console.ReadKey(true).KeyChar;
```

`Console.ReadKey` reads a single key from the console. When you pass the argument `true`, it intercepts the input so that it doesn't get printed to the console. Adding `.KeyChar` causes it to return the key pressed as a `char`.

Delete the "Hello, World!" line from your `Program.cs` file and **add these top-level statements**:

```
using AbilityScore;

AbilityScoreCalculator calculator = new AbilityScoreCalculator();
while (true)
{
    calculator.RollResult = ReadInt(calculator.RollResult, "Starting 4d6 roll");
    calculator.DivideBy = ReadDouble(calculator.DivideBy, "Divide by");
    calculator.AddAmount = ReadInt(calculator.AddAmount, "Add amount");
    calculator.Minimum = ReadInt(calculator.Minimum, "Minimum");
    calculator.CalculateAbilityScore();
    Console.WriteLine("Calculated ability score: " + calculator.Score);
    Console.WriteLine("Press Q to quit, any other key to continue");
    char keyChar = Console.ReadKey(true).KeyChar;
    if ((keyChar == 'Q') || (keyChar == 'q')) return;
}
```

Step 2: The code you wrote calls a method called `ReadInt`, so **add a static `ReadInt` method**. The `ReadInt` method takes two parameters: a string called **prompt** to display to the user, and an int called **defaultValue**. It writes the prompt to the console, followed by the default value in square brackets. Then it reads a line from the console and attempts to parse it with `int.TryParse`. If that returns true, return that value; otherwise, return the default value.

Here's the declaration:

```
static int ReadInt(int defaultValue, string prompt)
```

Calling `ReadInt("37", "What's the magic number?")` will cause the following prompt to be printed:

```
What's the magic number? [37]
```

There's a space at the end of that prompt. The user then types in a value and presses Enter. The method reads that line from the console and calls `int.TryParse` to try to parse it. If `int.TryParse` returns true, the method returns the result. If it returns false, the method returns `defaultValue`—in this case, 37.

Step 3: Generate and implement the `ReadDouble` method. `ReadDouble` is exactly like `ReadInt`, except that **it uses `double.TryParse`** instead of `int.TryParse`. The `double.TryParse` method works exactly like `int.TryParse`, except its **out** variable needs to be a double, not an int.

```
static double ReadDouble(double defaultValue, string prompt)
```

Exercise Solution

Here are the `ReadInt` and `ReadDouble` methods that display a prompt that includes the default value, read a line from the console, try to convert it to an int or a double, and either use the converted value or the default value, writing a message to the console with the value returned.

```
static int ReadInt(int defaultValue, string prompt)
{
    Console.Write(prompt + " [" + defaultValue + "]: ");
    string? line = Console.ReadLine();
    if (int.TryParse(line, out int value))
    {
        Console.WriteLine("    using value " + value);
        return value;
    } else
    {
        Console.WriteLine("    using default value " + defaultValue);
        return defaultValue;
    }
}

static double ReadDouble(double defaultValue, string prompt)
{
    Console.Write(prompt + " [" + defaultValue + "]: ");
    string? line = Console.ReadLine();
    if (double.TryParse(line, out double value))
    {
        Console.WriteLine("    using value " + value);
        return value;
    }
    else
    {
        Console.WriteLine("    using default value " + defaultValue);
        return defaultValue;
    }
}
```

Really take some time to understand how each iteration of the while loop in the top-level statements uses *fields* to save the values that the user entered, then uses them for the default values in the next iteration.

Try experimenting with the global namespace by removing “using AbilityScore;” from the top-level statements. What else do you need to do to change the code to build?



Thanks for writing this app for me! I can't wait to try it out.

Try changing the `csproj.debug.console` setting to the external Terminal to run your app in an external terminal window. You might prefer debugging your apps that way! ↓



Did you get a “cannot read keys when either application does not have a console” error in VSCode? If you did, go back to Chapter 1 and follow the instructions to change the C# debug console setting so your console app runs in the Terminal and not the Debug Console.

Here's the output from the app.

```

Starting 4d6 roll [14]: 18
  using value 18
Divide by [1.75]: 2.15
  using value 2.15
Add amount [2]: 5
  using value 5
Minimum [3]:
  using default value 3
Calculated ability score: 13
Press Q to quit, any other key to continue
Starting 4d6 roll [18]:
  using default value 18
Divide by [2.15]: 3.5
  using value 3.5
Add amount [13]: 5
  using value 5
Minimum [3]:
  using default value 3
Calculated ability score: 10
Press Q to quit, any other key to continue
Starting 4d6 roll [18]:
  using default value 18
Divide by [3.5]:
  using default value 3.5
Add amount [10]: 7 ←
  using value 7
Minimum [3]:
  using default value 3
Calculated ability score: 12
Press Q to quit, any other key to continue
Starting 4d6 roll [18]:
  using default value 18
Divide by [3.5]:
  using default value 3.5
Add amount [12]: 4 ←
  using value 4
Minimum [3]:
  using default value 3
Calculated ability score: 9
Press Q to quit, any other key to continue
Starting 4d6 roll [18]:
  using default value 18
Divide by [3.5]:
  using default value 3.5
Add amount [9]: ←
  using default value 9
Minimum [3]:
  using default value 3
Calculated ability score: 14
Press Q to quit, any other key to continue
    
```

Something's wrong. It's supposed to remember the values I enter, but it doesn't always work.

Look!
In the first iteration, I entered 5 for the add amount. It remembered all the other values just fine, but it gave me a default add amount of 10. That's the wrong result.



That's strange. Owen entered 5 for the previous add amount, but the program is giving him 10 as a default option.

Again, the last amount Owen entered was 7, but it's giving 12 as a default option. Weird.

Where did this 9 number come from? Did we see it before? Can that give us a hint about what's causing this bug?

You're right, Owen. There's a bug in the code.

Owen wants to try out different values to use in his ability score formula, so we used a loop to make the app ask for those values over and over again.

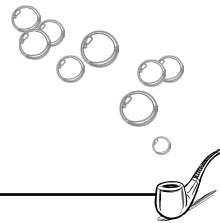
To make it easier for Owen to just change one value at a time, we included a feature in the app that remembers the last values he entered and presents them as default options. We implemented that feature by keeping an instance of the AbilityScoreCalculator class in memory, and updating its fields in each iteration of the **while** loop.

But something's gone wrong with the app. It remembers most of the values just fine, but it remembers the wrong number for the "add amount" default value. In the first iteration Owen entered 5, but it gave him 10 as a default option. Then he entered 7, but it gave a default of 12. What's going on?



Brain Power

What steps can you take to track down the bug in the ability score calculator app?



Sleuth it Out

The Case of the Operator Oddity

The debugger is like a detective's magnifying glass. It helps you spot even the smallest clues.

Let's do an investigation and see if we can apprehend the culprit, Sherlock Holmes style. **Something** is causing the bug, so let's use the debugger to identify suspects and retrace their steps.

The problem seems to be isolated to the "add amount" value, so let's start by looking for any line of code that touches the AddAmount field. Here's the line that uses the AddAmount field—put a breakpoint on it (and don't forget to use F5 to start your app with debugging if the breakpoint doesn't fire):

```

39 calculator.DivideBy = ReadDouble(calculator.DivideBy, "Divide by");
40 calculator.AddAmount = ReadInt(calculator.AddAmount, "Add amount");
41 calculator.Minimum = ReadInt(calculator.Minimum, "Minimum");

```

Here's another one in the AbilityScoreCalculator.CalculateAbilityScore method—breakpoint that suspect too:

```

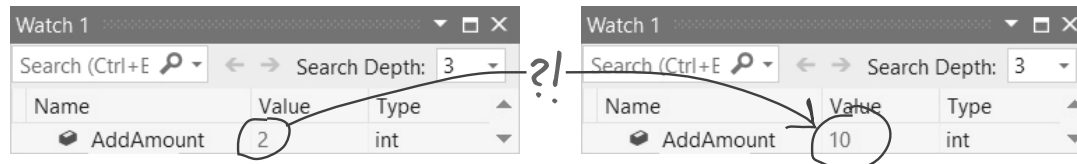
20 // Add to the result
21 int added = AddAmount += (int)divided;

```

The trap is set. Let's see who springs it.

Now run your program. When your code hits the breakpoint, **select calculator.AddAmount and add a watch** (if you just right-click on AddAmount and choose Add Watch from the menu, it will only add a watch for AddAmount and not calculator.AddAmount). Does anything look weird there? We're not seeing anything unusual. It seems to read the value and update it just fine—that's probably not the issue. You can delete that breakpoint.

Continue running your program. When the breakpoint in AbilityScoreCalculator.CalculateAbilityScore is hit, **add a watch for AddAmount**. According to Owen's formula, this line of code is supposed to add AddAmount to the result of dividing the roll result. Now **step over** the statement and...



Wait, what?! AddAmount changed. But...but that's not supposed to happen—it's impossible! Right? As Sherlock Holmes said, "When you have eliminated the impossible, whatever remains, however improbable, must be the truth."

It looks like we've sleuthed out the source of the problem. That statement is supposed to cast **divided** to an int to round it down to an integer, then add it to AddAmount and store the result in **added**. It also has an unexpected side effect: it's updating AddAmount with the sum because **the statement uses the += operator**, which returns the sum but assigns the sum to AddAmount.

Now we can finally fix Owen's bug—and get the REAL Sharpen answer

Now that you know what's happening, you can **fix the bug**—and it turns out to be a pretty small change. You just need to change the statement to use `+` instead of `+=`:

```
int added = AddAmount + (int)divided;
```

← Change the `+=` to a `+` to keep this line of code from updating the "added" variable and fix the bug.

And we can finally have the *real* answer to the "Sharpen your pencil" question in the first part of this project.

After you **circle the line of code that has problems**, look at the error and write down what you need to do to fix it.

First, it won't compile because `AddAmount += divided` is a double, so a cast needs to happen to assign it to an int. Second, it uses `+=` and not `+`, which causes the line to update `AddAmount`.

there are no Dumb Questions

Q: I'm still not clear on the difference between the `+` operator and the `+=` operator. How do they work, and why would I use one and not the other?

A: There are several operators that you can combine with an equals sign. They include `+=` for adding, `-=` for subtracting, `/=` for dividing, `*=` for multiplying, and `%=` for remainder. Operators like `+` that combine two values are called **binary operators**. Some people find this name a little confusing, but "binary" refers to the fact that the operator combines two values—"binary" means "involving two things"—not that it somehow operates only on binary numbers.

With binary operators, you can do something called **compound assignment**, which means instead of this:

```
a = a + c;
```

you can do this:

```
a += c;
```

The `+=` operator tells C# to add `a + c` and then store the result in `a`.

and it means the same thing. The compound assignment `x op= y` is equivalent to `x = x op y` (that's the technical way of explaining it). They do exactly the same thing.

Operators like `+=` or `*=` that combine a binary operator with an equals sign are called **compound assignment operators.**

Q: But then how did the `added` variable get updated?

A: What caused confusion in the score calculator is that the **assignment operator `=` also returns a value**. You can do this:

```
int q = (a = b + c)
```

which will calculate `a = b + c` as usual. The `=` operator **returns** a value, so it will update `q` with the result as well. So:

```
int added = AddAmount += divided;
```

is just like doing this:

```
int added = (AddAmount = AddAmount + divided);
```

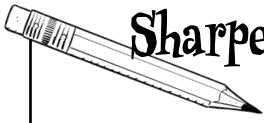
which causes `AddAmount` to be increased by `divided`, but stores that result in `added` as well.

Q: Wait, what? The equals operator returns a value?

A: Yes, `=` returns the value being set. So in this code:

```
int first;
int second = (first = 4);
```

both `first` and `second` will end up equal to 4. Open up a console app and use the debugger to test this. It really works!



Sharpen your pencil

We learned about XML Documentation Comments (or XMLDoc) in Chapter 3. We added XMLDoc to the `ReadInt` method from your Ability Score Calculator app—but we left a lot of blanks for you to fill in. Go back to the section in Chapter 3 where we talked about XMLDoc and try filling in the missing parts of the XMLDoc.

```
/// <.....>
/// .....
/// </.....>
/// <..... name="defaultValue">
/// .....
/// </.....>
/// <..... name="prompt">
/// .....
/// </.....>
/// <returns>
/// .....
/// </returns>
static int ReadInt(int defaultValue, string prompt)
{
```

In the examples we showed you in Chapter 3, the opening `<returns>` tag was on the same line as the closing `</returns>` tag. In this exercise, we put them on separate lines to give you more space to describe what the method returns.

We aren't giving you a solution for this "Sharpen" pencil-and-paper exercise. Instead, use the responses that the AI chatbots give you in the next "Sens-AI" section—compare them against your answers to see how you did.

- We asked you to fill in six blanks for three pairs of opening and closing tags. Did you get them right?
- We gave you four blanks to describe what the method does, its parameters, and return values. Compare your responses with the ones the chatbots generated. Do you agree with their descriptions? Remember—AIs don't always get everything right. You wrote this code, so your descriptions might be more accurate than the AI's.



Ask an AI chatbot to add comments to your code

Adding **comments** to your code is a great habit to get into. We've used comments throughout the first few chapters of this book to help you understand the code we've written. Comments are really valuable, for a few reasons:

- Every developer knows what it feels like to look at code they wrote a long time ago and have absolutely no idea what it does or how it works. This happens a lot when working on a larger app (like the ones you'll write later in the book). Comments help us remember what we were thinking when we wrote code.
- Sometimes you've got a particularly complex bit of code, like the event handler method for the buttons in the animal matching game from Chapter 1. Comments can make it easier for you to figure out what's going on in that code—which can be really valuable if you're trying to sleuth out a bug.
- Developers will often leave themselves comments like this:

```
//TODO: Finish this piece of code
```

as a reminder that there's still work left to do in one part of an app.

This is a great use of an AI chatbot as a learning tool. We've given you a lot of information about comments. Now you can use AI to learn more on your own.

These are three really good reasons that developers use comments, but there are many other ways—so many that there's no way we could possibly include them all in this book. Here's an opportunity to learn more on your own.

Open an AI chatbot and give it this prompt: **Why do developers use comments?**

There are many answers to this question, because there are lots of reasons that developers use comments. Try giving this prompt to more than one AI chatbot, or asking it multiple times.

Create a prompt to add comments to your code

Start a new session with an AI chatbot and **give it the following prompt:**

Here are the contents of Program.cs:

<paste in the contents of your Program.cs file>

Here are the contents of AbilityScoreCalculator.cs:

<paste in the contents of the file with the AbilityScoreCalculator class>

Use AI chatbots to learn more about XML Documentation

In Chapter 3 we learned about XML Documentation (or XMLDoc), special comments with three slashes that you can use to document your methods, fields, and other class members. AI chatbots are really good at generating XMLDoc.

Start a new AI chatbot session, and give it exactly the same prompt you just gave it for the comments, except replace the first sentence of the prompt with this one, which asks it to generate XMLDoc where it's needed.

Add comments to the code for this C# console application, using XMLDoc for the classes, methods, and fields.

Compare the response from the AI against your answers to the “Sharpen” exercise. Which descriptions are better?

Try this! →

Try adding this `if/else` statement to a console app and build the solution:

```
if (0.1M + 0.2M == 0.3M) Console.WriteLine("They're equal");
else Console.WriteLine("They aren't equal");
```

You'll see a green squiggle under the second `Console`—it's an **Unreachable code detected** warning. The C# compiler knows that $0.1 + 0.2$ is always equal to 0.3 , so the code will never reach the `else` part of the statement. Run the code—it prints **They're equal** to the console.

Next, **change the float literals to doubles** (remember, literals like `0.1` default to double):

```
if (0.1 + 0.2 == 0.3) Console.WriteLine("They're equal");
else Console.WriteLine("They aren't equal");
```

That's really strange. The warning moved to the first line of the `if` statement. Try running the program. Hold on, that can't be right! It printed **They aren't equal** to the console. How is $0.1 + 0.2$ not equal to 0.3 ?

Now do one more thing. Change `0.3` to `0.3000000000000000004` (with 15 zeros between the 3 and 4). Now it prints **They're equal** again. So apparently $0.1D$ plus $0.2D$ equals `0.3000000000000000004D`.

Hey, kid! Wanna see something **WEIRD**?



← Wait, what?!

So is that why I should only use the **decimal type** for money, and never use **double** for currency values?



Exactly. Decimal has a lot more precision than double or float, so it avoids the 0.3000000000000000004 problem.

Some floating-point types—not just in C#, but in most programming languages!—can give you **rare** weird errors. This is so strange! How can $0.1 + 0.2$ be `0.3000000000000000004`?

It turns out that some numbers *can't be exactly represented* as a double—it has to do with how they're stored as binary data (0s and 1s in memory). For example, `.1D` is not *exactly* `.1`. Try multiplying `.1D * .1D`—you get `0.0100000000000000002`, not `0.01`. But `.1M * .1M` gives you the right answer. That's why floats and doubles are really useful for a lot of things (like positioning a `GameObject` in Unity). If you need more rigid precision—like for a financial app that deals with money—decimal is the way to go.

there are no
Dumb Questions

Q: I'm still not clear on the difference between conversion and casting. Can you explain it a little more clearly?

A: "Conversion" is a general, all-purpose term for converting data from one type to another. Casting is a much more specific operation, with explicit rules about which types can be cast to other types, and what to do when the data for the value from one doesn't quite match the type it's being cast to. You just saw an example of one of those rules—when a floating-point number is cast to an int, it's rounded down by dropping any decimal value. You saw another rule earlier about wrapping for integer types, where a number that's too big to fit into the type it's being cast to is wrapped using the remainder operator.

Q: Hold on a minute. Earlier you had me "wrap" numbers myself using the mod function on my calculator app. Now you're talking about remainders. What's the difference?

A: Mod and remainder are very similar operations. For positive numbers they're exactly the same: $A \% B$ is the remainder when you divide B into A , so: $5 \% 2$ is the remainder of $5 \div 2$, or 1. (If you're trying to remember how long division works, that just means that $5 \div 2$ is equal to $2 \times 2 + 1$, so the rounded quotient is 2 and the remainder is 1.) But when you start dealing with negative numbers, there's a difference between mod (or modulus) and remainder. You can see for yourself: your calculator will tell you that $-397 \bmod 17 = 11$, but if you use the C# remainder operator you'll get $-397 \% 17 = -6$.

If you're math oriented and want to challenge yourself, here's a good research topic: see if you can find an explanation for why mod acts differently on a calculator versus in C#. Try asking your favorite AI to help explain it.

Q: Owen's formula had me dividing two values and then rounding the result down to the nearest integer. How does that fit in with casting?

A: Let's say you have some floating-point values:

```
float f1 = 185.26F;
double d2 = .0000316D;
decimal m3 = 37.26M;
```

and you want to cast them to int values so you can assign them to int variables `i1`, `i2`, and `i3`. We know that those int variables can only hold integers, so your program needs to do *something* to the decimal part of the number.

So C# has a consistent rule: it drops the decimal and rounds down: `f1` becomes 185, `d2` becomes 0, and `m3` becomes 37. But don't take our word for it—write your own C# code that casts those three floating-point values to int to see what happens.

Q: Is there a way to make literals easier to read, like how we put commas in really long numbers?

A: Yes. You can use **underscores** to make literals in your code easier to read. If you want to store 8,675,309 in an int, you can add a `_` for each comma:

```
int i = 8_675_309;
```

That works for other literal types, too, including byte, float, double, and decimal.

There's a whole web page dedicated to the `0.30000000000000004` problem! Check out <https://0.30000000000000004.com> to see examples in a lot of different languages.

The `0.1D + 0.2D != 0.3D` example is an *edge case*, or a problem or situation that only happens under certain rare conditions, usually when a parameter is at one of its extremes (like a very big or very small number). If you want to learn more about it, there's a great article by Jon Skeet about how floating-point numbers are stored in memory in .NET: <https://csharpindepth.com/Articles/FloatingPoint>



Jon gave us some amazing technical review feedback for the very first edition of this book, and that made a huge difference for us. Thanks so much, Jon!

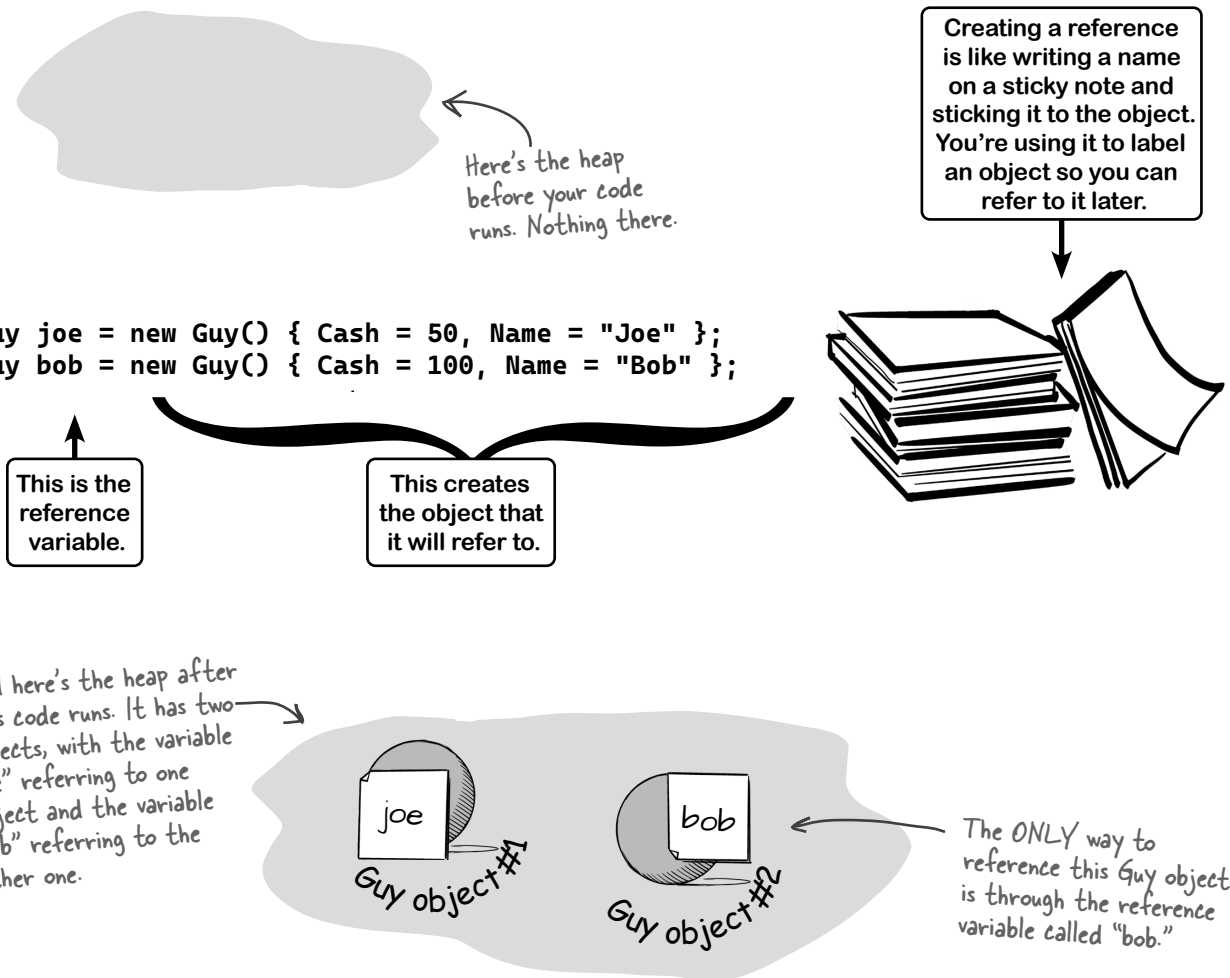
Use reference variables to access your objects

When you create a new object, you use a **new** statement to instantiate it, like `new Guy()` in your program at the end of Chapter 3—the **new** statement created a new `Guy` object on the heap. You still needed a way to *access* that object, and that’s where a variable like `joe` came in: `Guy joe = new Guy()`. Let’s dig a little deeper into exactly what’s going on there.

The **new** statement creates the instance, but just creating that instance isn’t enough. **You need a reference to the object.** So you created a **reference variable**: a variable of type `Guy` with a name, like `joe`. So `joe` is a reference to the new `Guy` object you created. Any time you want to use that particular `Guy`, you can reference it with the reference variable called `joe`.

When you have a variable that’s an object type, it’s a reference variable: a reference to a particular object. Let’s just make sure we get the terminology right since we’ll be using it a lot. We’ll use the first two lines of the “Joe and Bob” program from the previous chapter:

```
Guy joe = new Guy() { Cash = 50, Name = "Joe" };  
Guy bob = new Guy() { Cash = 100, Name = "Bob" };
```

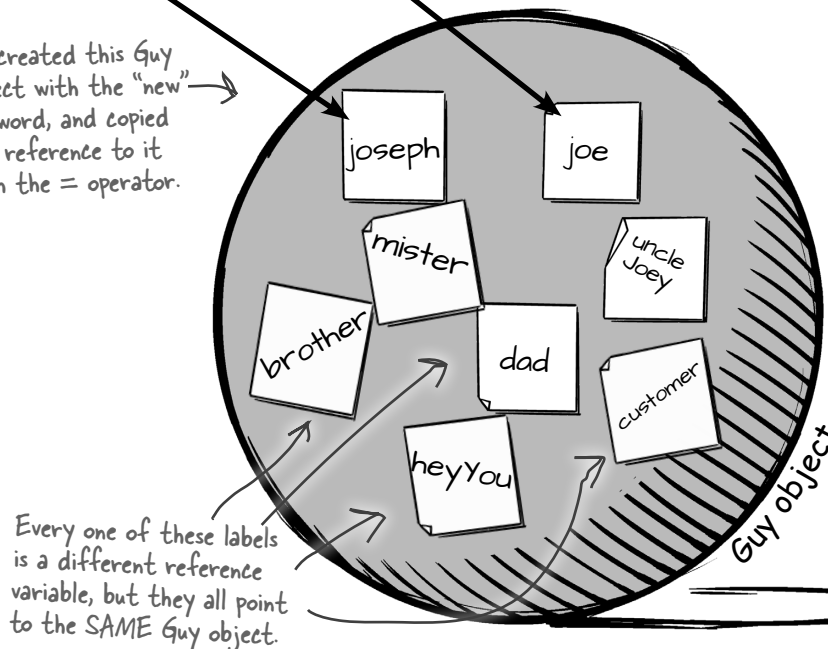


References are like sticky notes for your objects

In your kitchen, you probably have containers of salt and sugar. If you switched their labels, it would make for a pretty disgusting meal—even though you changed the labels, the contents of the containers stayed the same. **References are like labels.** You can move labels around and point them at different things, but it's the **object** that dictates what methods and data are available, not the reference itself—and you can **copy references** just like you copy values.

```
Guy joe = new Guy();
Guy joseph = joe;
```

We created this Guy object with the "new" keyword, and copied the reference to it with the = operator.



We stuck a lot of sticky notes on that object! In this particular case, there are a lot of different references to this same Guy object—because a lot of different methods use it for different things. Each reference has a different name that makes sense in its context.

That's why it can be really useful to have **multiple references pointing to the same instance**. So you could say `Guy dad = joe`, and then call `dad.GiveCash()` (that's what Joe's kid does every day). If you want to write code that works with an object, you need a reference to that object. If you don't have that reference, you have no way to access the object.

A reference is like a label that your code uses to talk about a specific object. You use it to access fields and call methods on an object that it points to.

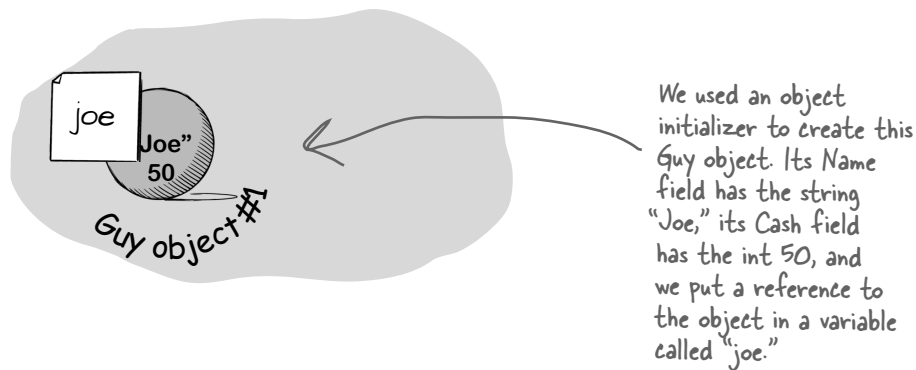
If there aren't any more references, your object gets garbage-collected

If all of the labels come off of an object, programs can no longer access that object. That means C# can mark the object for **garbage collection**. That's when C# gets rid of any unreferenced objects and reclaims the memory those objects took up for your program's use.

1 Here's some code that creates an object.

Just to recap what we've been talking about: when you use the **new** statement, you're telling C# to create an object. When you take a reference variable like **joe** and assign it to that object, it's like you're slapping a new sticky note on it.

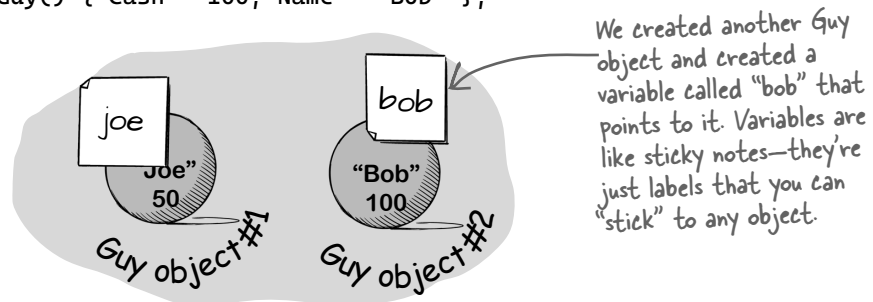
```
Guy joe = new Guy() { Cash = 50, Name = "Joe" };
```



2 Now let's create our second object.

Once we do this we'll have two Guy object instances and two reference variables: one variable (**joe**) for the first Guy object, and another variable (**bob**) for the second.

```
Guy bob = new Guy() { Cash = 100, Name = "Bob" };
```



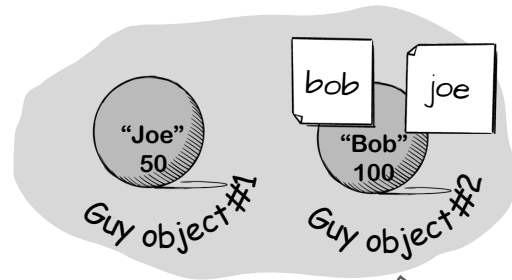
3 Let's take the reference to the first Guy object and change it to point to the second Guy object.

Take a really close look at what you're doing when you create a new Guy object. You're taking a variable and using the = assignment operator to set it—in this case, to a reference that's returned by the `new` statement. That assignment works because **you can copy a reference just like you copy a value**.

So let's go ahead and copy that value:

```
joe = bob;
```

That tells C# to make `joe` point to the same object that `bob` does. Now the `joe` and `bob` variables **both point to the same object**.

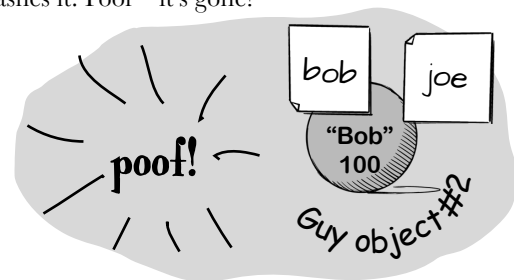


After the CLR (coming up in the "Garbage Collection Exposed" interview!) removes the last reference to the object, it marks it for garbage collection.

4 There's no longer a reference to the first Guy object...so it gets *garbage-collected*.

Now that `joe` is pointing to the same object as `bob`, there's no longer a reference to the Guy object it used to point to. So what happens? C# marks the object for garbage collection, and **eventually** trashes it. Poof—it's gone!

The CLR keeps track of all of the references to each object, and when the last reference disappears, it marks it for removal. But it might have other things to do right now, so the object could stick around for a few milliseconds—or even longer!

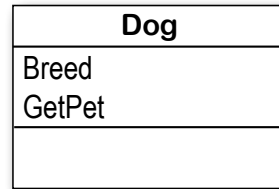


For an object to stay in the heap, it has to be referenced. Sometime after the last reference to the object disappears, so does the object.

```
public partial class Dog {
    public void GetPet() {
        Console.WriteLine("Woof!");
    }
}
```

Multiple references and their side effects

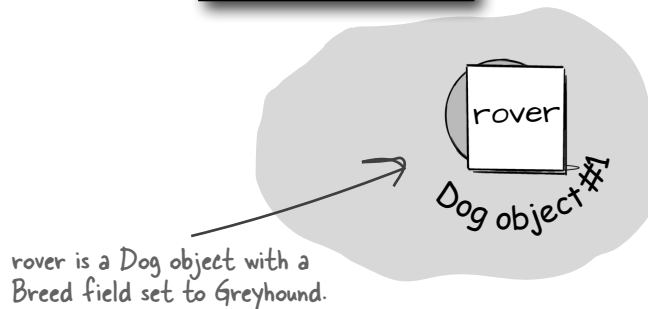
You've got to be careful when you start moving reference variables around. Lots of times, it might seem like you're simply pointing a variable to a different object. You could end up removing all references to another object in the process. That's not a bad thing, but it may not be what you intended. Take a look:



```
1 Dog rover = new Dog();
  rover.Breed = "Greyhound";
```

Objects: 1

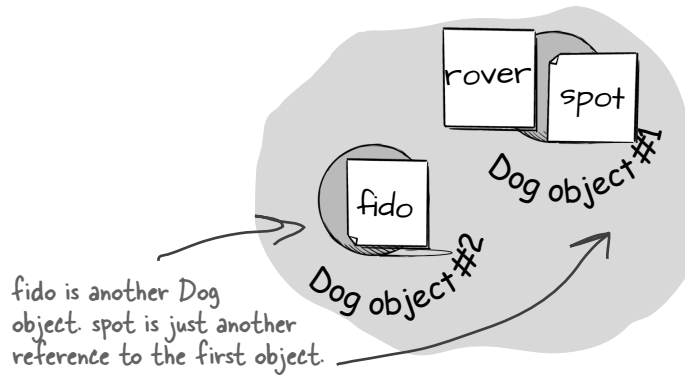
References: 1



```
2 Dog fido = new Dog();
  fido.Breed = "Beagle";
  Dog spot = rover;
```

Objects: 2

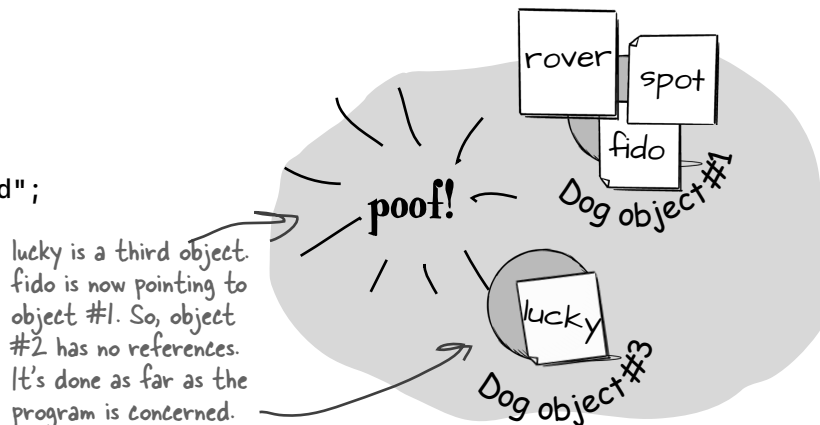
References: 3



```
3 Dog lucky = new Dog();
  lucky.Breed = "Dachshund";
  fido = rover;
```

Objects: 2

References: 4





Sharpen your pencil

Now it's your turn. Here's one long block of code. Figure out how many objects and references there are at each stage. On the righthand side, draw a picture of the objects and sticky notes in the heap.

1 `Dog rover = new Dog();`
`rover.Breed = "Greyhound";`
`Dog rinTinTin = new Dog();`
`Dog fido = new Dog();`
`Dog bear = fido;`

Objects:_____

References:_____

2 `Dog spot = new Dog();`
`spot.Breed = "Dachshund";`
`spot = rover;`

Objects:_____

References:_____

3 `Dog lucky = new Dog();`
`lucky.Breed = "Beagle";`
`Dog charlie = fido;`
`fido = rover;`

Objects:_____

References:_____

4 `rinTinTin = lucky;`
`Dog laverne = new Dog();`
`laverne.Breed = "pug";`

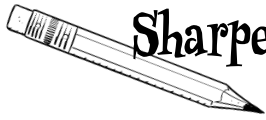
Objects:_____

References:_____

5 `charlie = laverne;`
`lucky = rinTinTin;`

Objects:_____

References:_____



Sharpen your pencil Solution

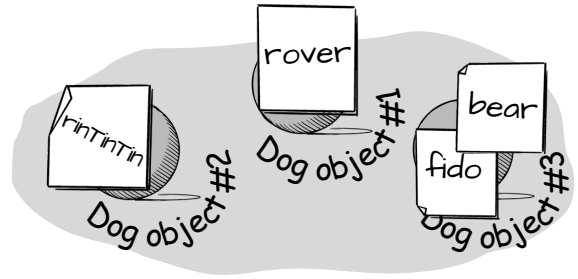
```

1 Dog rover = new Dog();
  rover.Breed = "Greyhound";
  Dog rinTinTin = new Dog();
  Dog fido = new Dog();
  Dog bear = fido;
    
```

Objects: 3

References: 4

One new Dog object is created, but spot is the only reference to it. When spot is set to rover, that object goes away.

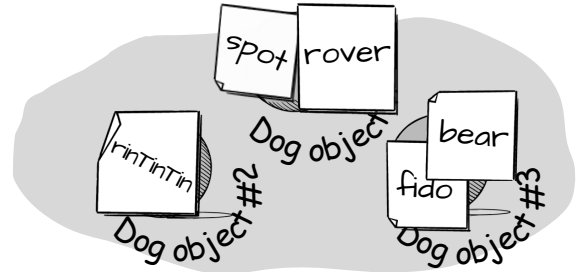


```

2 Dog spot = new Dog();
  spot.Breed = "Dachshund";
  spot = rover;
    
```

Objects: 3

References: 5



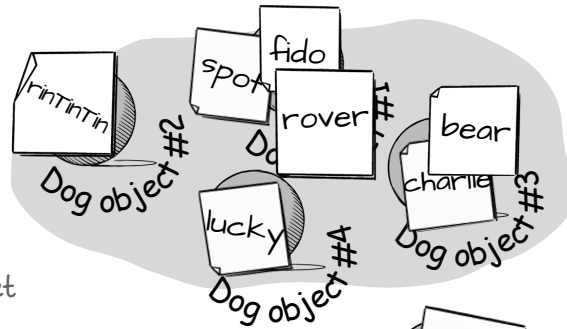
```

3 Dog lucky = new Dog();
  lucky.Breed = "Beagle";
  Dog charlie = fido;
  fido = rover;
    
```

Objects: 4

References: 7

charlie was set to fido when fido was still on object #3. Then, after that, fido moved to object #1, leaving charlie behind.



```

4 rinTinTin = lucky;
  Dog laverne = new Dog();
  laverne.Breed = "pug";
    
```

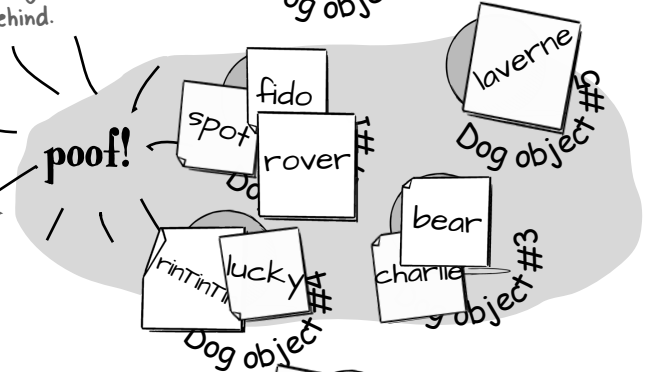
Objects: 4

References: 8

Dog #2 lost its last reference, and it went away.

poof!

When rinTinTin moved to lucky's object, the old rinTinTin object disappeared.



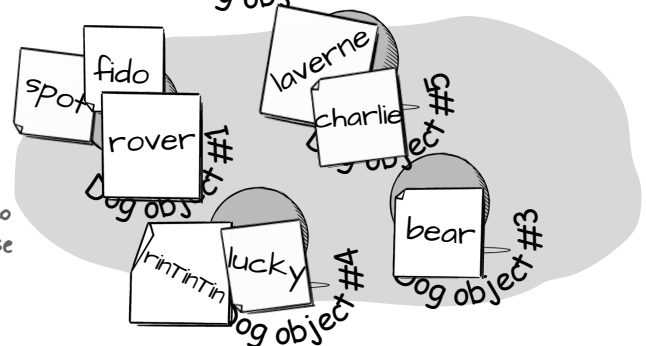
```

5 charlie = laverne;
  lucky = rinTinTin;
    
```

Objects: 4

References: 8

Here the references move around, but no new objects are created. Setting lucky to rinTinTin did nothing because they already pointed to the same object.





Garbage Collection Exposed

This week's interview: The .NET Common Language Runtime

Head First: So, we understand that you do a pretty important job for us. Can you tell us a little more about what you do?

Common Language Runtime (CLR): In a lot of ways, it's pretty simple. I run your code. Any time you're using a .NET app, I'm making it work.

Head First: What do you mean by making it work?

CLR: I take care of the low-level “stuff” for you by doing a sort of “translation” between your program and the computer running it. When you talk about instantiating objects or doing garbage collection, I'm the one that's managing all of those things.

Head First: So how does that work, exactly?

CLR: Well, when you run a program on Windows, macOS, Linux, or most other operating systems, the OS loads machine language from a **binary**.

Head First: I'm going to stop you right there. Can you back up and tell us what machine language is?

CLR: Sure. A program written in machine language is made up of code that's executed directly by the CPU—and it's a whole lot less readable than C#.

Head First: If the CPU is executing the actual machine code, what does the OS do?

CLR: The OS makes sure each program gets its own process, respects the security rules, and provides APIs.

Head First: And for our readers who don't know what an API is?

CLR: An **API**—or **application programming interface**—is a set of methods provided by an OS, library, or program. OS APIs help you do things like work with the filesystem and interact with hardware. But they're often pretty difficult to use—especially for memory management—and they vary from OS to OS.

Head First: So back to your job. You mentioned a binary. What exactly is that?

CLR: A binary is a file that's (usually) created by a **compiler**, a program whose job it is to convert high-level language into low-level code like machine code. Windows binaries usually end with *.exe* or *.dll*.

Head First: But I'm guessing that there's a twist here. You said “low-level code like machine code”—does that mean there are other kinds of low-level code?

CLR: Exactly. I don't run the same machine language as the CPU. When you build your C# code, Visual Studio asks the C# compiler to create **Common Intermediate Language (CIL)**. That's what I run. C# code is turned into CIL, which I read and execute.

Head First: You talked about Windows binaries. But you also work on macOS. How does that work?

CLR: If you look in the folders created for your Visual Studio for Mac projects, you'll see lots of files that end with *.dll*. These are **managed .NET DLL files**, and they contain CIL code for the app. You can **run those apps from the command line** anywhere I'm installed! Try it out for yourself. Open a console window, go to the folder with the PickRandomCards project from Chapter 3, find the folder under *bin/* that has files that end with *.dll*, and run this: **dotnet PickRandomCards.dll**.

Head First: You mentioned managing memory. Is that where garbage collection fits into all of this?

CLR: Yes! One useful thing that I do for you is manage your computer's memory by figuring out when your app is done with certain objects. When it is, I get rid of them for you to free up that memory. That's something programmers used to have to do themselves—but thanks to me, it's something that you don't have to be bothered with. You might not have known it at the time, but I've been making your job of learning C# a whole lot easier.

You can run your console apps from the command line. Find the DLL file underneath the *bin/* folder and run it like this: **dotnet ProjectName.dll**—and this will work on any OS you can install .NET on—even Linux!

Exercise

Create a program with an Elephant class. Instantiate two Elephant instances and then swap the reference values that point to them, *without* getting any Elephant instances garbage-collected. Here's what it will look like when your program runs.

You're going to build a new console app that has a class called Elephant.

Here's an example of the output of the program:

Press 1 for Lloyd, 2 for Lucinda, 3 to swap

You pressed 1

Calling lloyd.WhoAmI()

My name is Lloyd.

My ears are 40 inches tall.

You pressed 2

Calling lucinda.WhoAmI()

My name is Lucinda.

My ears are 33 inches tall.

You pressed 3

References have been swapped

You pressed 1

Calling lloyd.WhoAmI()

My name is Lucinda.

My ears are 33 inches tall.

You pressed 2

Calling lucinda.WhoAmI()

My name is Lloyd.

My ears are 40 inches tall.

You pressed 3

References have been swapped

You pressed 1

Calling lloyd.WhoAmI()

My name is Lloyd.

My ears are 40 inches tall.

You pressed 2

Calling lucinda.WhoAmI()

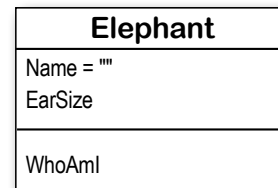
My name is Lucinda.

My ears are 33 inches tall.

The Elephant class has a WhoAmI method that writes these two lines to the console to display the values in the Name and EarSize fields.

Swapping the references causes the lloyd variable to call the Lucinda object's method, and vice versa.

Here's the class diagram for the Elephant class you'll need to create.



Swapping them again returns things to the way they were when the program started.

When you create your Elephant class, declare your Name field like this:

```
public string Name = "";
```

This sets the Name field to an empty string. Why do you think we're asking you to do that?

The CLR garbage-collects any object with no references to it. So here's a hint for this exercise: if you want to pour a cup of coffee into another cup that's currently full of tea, you'll need a third glass to pour the tea into...

Exercise

Your job is to create a console app with an Elephant class that matches the class diagram and uses its fields and methods to generate output that matches the example output.

1 Create a new console app and add the Elephant class.

Add an Elephant class to the project. Have a look at the Elephant class diagram—you'll need an int field called EarSize and a string field called Name. Add them, and make sure both are public. Then add a method called WhoAmI that writes two lines to the console to tell you the name and ear size of the elephant. Look at the example output to see exactly what it's supposed to print.

2 Create two Elephant instances and a reference.

Use object initializers to instantiate two Elephant objects:

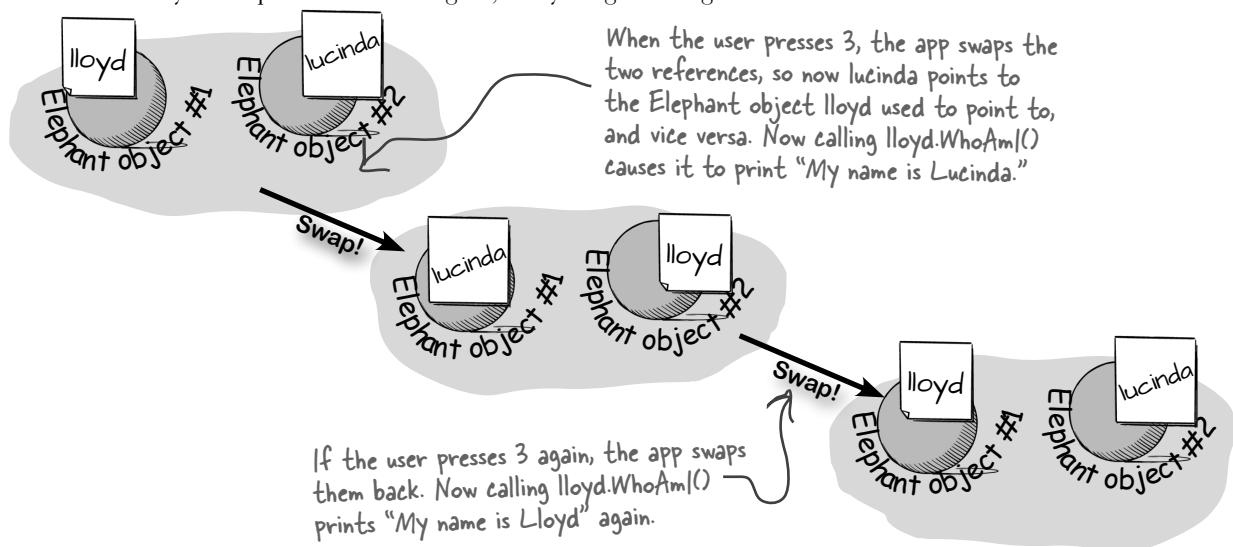
```
Elephant lucinda = new Elephant() { Name = "Lucinda", EarSize = 33 };
Elephant lloyd = new Elephant() { Name = "Lloyd", EarSize = 40 };
```

3 Call their WhoAmI methods.

When the user presses 1, call lloyd.WhoAmI. When the user presses 2, call lucinda.WhoAmI. Make sure that the output matches the example. This is a good place to use **else if**, which you learned about in Chapter 3.

4 Now for the fun part: swap the references.

Here's the interesting part of this exercise. When the user presses 3, make the app execute code that **exchanges the two references**. You'll need to write that method. After you swap references, pressing 1 should write Lucinda's message to the console, and pressing 2 should write Lloyd's message. If you swap the references again, everything should go back to normal.



Exercise Solution

There's more than one way to solve this exercise. If you came up with different code that works, that's great! Take the time to understand our solution.

Create a program with an Elephant class. Instantiate two Elephant instances and then swap the reference values that point to them, **without** getting any Elephant instances garbage-collected.

Here's the Elephant class:

```
class Elephant
{
    public int EarSize;
    public string Name = "";
    public void WhoAmI()
    {
        Console.WriteLine("My name is " + Name + ".");
        Console.WriteLine("My ears are " + EarSize + " inches tall.");
    }
}
```

We asked you to initialize the Name field like this.

Elephant
Name = ""
EarSize
WhoAmI

Here are the top-level statements for your *Program.cs* file:

```
Elephant lucinda = new Elephant() { Name = "Lucinda", EarSize = 33 };
Elephant lloyd = new Elephant() { Name = "Lloyd", EarSize = 40 };
```

```
Console.WriteLine("Press 1 for Lloyd, 2 for Lucinda, 3 to swap");
while (true)
```

```
{
    char input = Console.ReadKey(true).KeyChar;
    Console.WriteLine("You pressed " + input);
    if (input == '1')
    {
        Console.WriteLine("Calling lloyd.WhoAmI()");
        lloyd.WhoAmI();
    } else if (input == '2')
    {
        Console.WriteLine("Calling lucinda.WhoAmI()");
        lucinda.WhoAmI();
    } else if (input == '3')
    {
        Elephant holder;
        holder = lloyd;
        lloyd = lucinda;
        lucinda = holder;
        Console.WriteLine("References have been swapped");
    }
    else
    {
        return;
    }
    Console.WriteLine();
}
```

We used "else if" to check if the user entered 1, 2, or 3, and an else statement to exit if they entered anything else.

If you just point Lloyd to Lucinda, there won't be any more references pointing to Lloyd, and his object will be lost. That's why you need to have an extra variable (we called it "holder") to keep track of the Lloyd object reference until Lucinda can get there.



There's no "new" statement when we declare the "holder" variable because we don't want to create another instance of Elephant.

Two references mean TWO variables that can change the same object's data

Besides losing all the references to an object, when you have multiple references to an object, you can unintentionally change the object. In other words, one reference to an object may **change** that object, while another reference to that object has **no idea** that something has changed. Let's see how that works.

Add one more else if block to your top-level statements. Can you guess what will happen once it runs?

```

else if (input == '3')
{
    Elephant holder;
    holder = lloyd;
    lloyd = lucinda;
    lucinda = holder;
    Console.WriteLine("References have been swapped");
}
else if (input == '4')
{
    lloyd = lucinda;
    lloyd.EarSize = 4321;
    lloyd.WhoAmI();
}
else
{
    return;
}
    
```

After this statement, both the lloyd and lucinda variables reference the SAME Elephant object.

This statement says to set EarSize to 4321 on whatever object the reference stored in the lloyd variable happens to point to.

Now go ahead and run your program. Here's what you'll see:

You pressed 4
 My name is Lucinda
 My ears are 4321 inches tall.

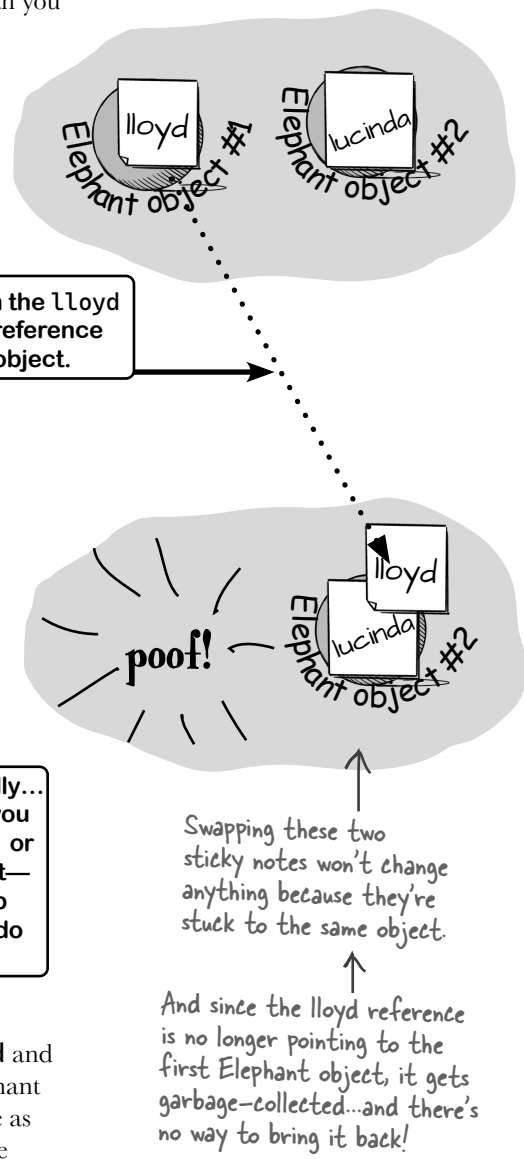
You pressed 1
 Calling lloyd.WhoAmI()
 My name is Lucinda
 My ears are 4321 inches tall.

You pressed 2
 Calling lucinda.WhoAmI()
 My name is Lucinda
 My ears are 4321 inches tall.

The program acts normally... until you press 4. Once you do that, pressing either 1 or 2 prints the same output—and pressing 3 to swap the references doesn't do anything anymore.

After you press 4 and run the new code that you added, both the **lloyd** and **lucinda** variables **contain the same reference** to the second Elephant object. Pressing 1 to call lloyd.WhoAmI prints exactly the same message as pressing 2 to call lucinda.WhoAmI. Swapping them makes no difference because you're swapping two identical references.

Do this!



Objects use references to talk to each other

So far, you've seen forms talk to objects by using reference variables to call their methods and check their fields. Objects can call one another's methods using references too. In fact, there's nothing that a form can do that your objects can't do, because your form is just another object. When objects talk to each other, one useful keyword that they have is **this**. Any time an object uses the **this** keyword, it's referring to itself—it's a reference that points to the object that calls it. Let's see what that looks like by modifying the Elephant class so instances can call each other's methods.

Elephant
Name
EarSize
WhoAml
HearMessage
SpeakTo

1 Add a method that lets an Elephant hear a message.

Let's add a method to the Elephant class. Its first parameter is a message from another Elephant object. Its second parameter is the Elephant object that sent the message:

```
public void HearMessage(string message, Elephant whoSaidIt) {
    Console.WriteLine(Name + " heard a message");
    Console.WriteLine(whoSaidIt.Name + " said this: " + message);
}
```

Do this!

Here's what it looks like when it's called:

```
lloyd.HearMessage("Hi", lucinda);
```

We called **lloyd's** `HearMessage` method, and passed it two parameters: the string **"Hi"** and a reference to Lucinda's object. The method uses its **whoSaidIt** parameter to access the `Name` field of whatever elephant was passed in.

2 Add a method that lets an Elephant send a message.

Now let's add a `SpeakTo` method to the Elephant class. It uses a special keyword: **this**. That's a reference that lets an object get a reference to itself.

```
public void SpeakTo(Elephant whoToTalkTo, string message) {
    whoToTalkTo.HearMessage(message, this);
}
```

An Elephant's `SpeakTo` method uses the "this" keyword to send a reference to itself to another Elephant.

Let's take a closer look at what's going on.

When we call the Lucinda object's `SpeakTo` method:

```
lucinda.SpeakTo(lloyd, "Hi, Lloyd!");
```

It calls the Lloyd object's `HearMessage` method like this:

```
whoToTalkTo.HearMessage("Hi, Lloyd!", this);
```

↓
Lucinda uses `whoToTalkTo`
(which has a reference to
Lloyd) to call `HearMessage`.

↘ `this` is replaced with
a reference to
Lucinda's object.

```
[a reference to Lloyd].HearMessage("Hi, Lloyd!", [a reference to Lucinda]);
```

3 Call the new methods.

Add one more **else if** block to the top-level statements to make the Lucinda object send a message to the Lloyd object:

```
else if (input == '4')
{
    lloyd = lucinda;
    lloyd.EarSize = 4321;
    lloyd.WhoAmI();
}
else if (input == '5')
{
    lucinda.SpeakTo(lloyd, "Hi, Lloyd!");
}
else
{
    return;
}
```

Now run your program and press 5. You should see this output:

```
You pressed 5
Lloyd heard a message
Lucinda said this: Hi, Lloyd!
```

**The “this”
keyword
lets an
object get
a reference
to itself.**

Remember, if your app doesn't pause on the breakpoint, make sure you're starting the app with debugging. Run the app by pressing F5 or choosing Start Debugging from the Debug (Visual Studio) or Run (VSCode) menu.

4 Use the debugger to understand what's going on.

Place a breakpoint on the statement that you just added:

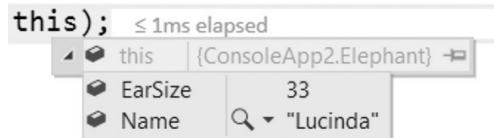


Run your program and press 5.

When it hits the breakpoint, use Debug >> Step Into (F11) to step into the SpeakTo method.

Add a watch for Name to show you which Elephant object you're inside. You're currently inside the Lucinda object—which makes sense because the app just called lucinda.SpeakTo.

Hover over the **this** keyword at the end of the line and expand it. It's a reference to the Lucinda object.



Hover over **whoToTalkTo** and expand it—it's a reference to the Lloyd object.

The SpeakTo method has one statement—it calls whoToTalkTo.HearMessage. Step into it.

You should now be inside the HearMessage method. Check your watch again—now the value of the Name field is “Lloyd”—the Lucinda object called the Lloyd object's HearMessage method.

Hover over **whoSaidIt** and expand it. It's a reference to the Lucinda object.

Finish stepping through the code. Take a few minutes to really understand what's going on.

Strings and arrays are different from the other data types you've seen in this chapter because they're the only ones without a set size (think about that for a bit).

Arrays hold multiple values

If you have to keep track of a lot of data of the same type, like a list of prices or a group of dogs, you can do it in an **array**. What makes an array special is that it's a **group of variables** that's treated as one object. An array gives you a way of storing and changing more than one piece of data without having to keep track of each variable individually. When you create an array, you declare it just like any other variable, with a name and a type—except **the type is followed by square brackets**:

```
bool[] myArray;
```

Use the **new** keyword to create an array. Let's create an array with 15 bool elements:

```
myArray = new bool[15];
```

Use square brackets to set one of the values in the array. This statement sets the value of the fifth element of **myArray** to **false** by using square brackets and specifying the **index** 4. It's the fifth one because the first is **myArray[0]**, the second is **myArray[1]**, etc.:

```
myArray[4] = false;
```

Use each element in an array like it's a normal variable

When you use an array, first you need to **declare a reference variable** that points to the array. Then you need to **create the array object** using the **new** statement, specifying how big you want the array to be. Then you can **set the elements** in the array. Here's an example of code that declares and fills up an array—and what's happening in the heap when you do it. The first element in the array has an **index** of 0.

```
// declare a new 7-element decimal array
decimal[] prices = new decimal[7];
prices[0] = 12.37M;
prices[1] = 6_193.70M;

// we didn't set the element
// at index 2, it remains
// the default value of 0

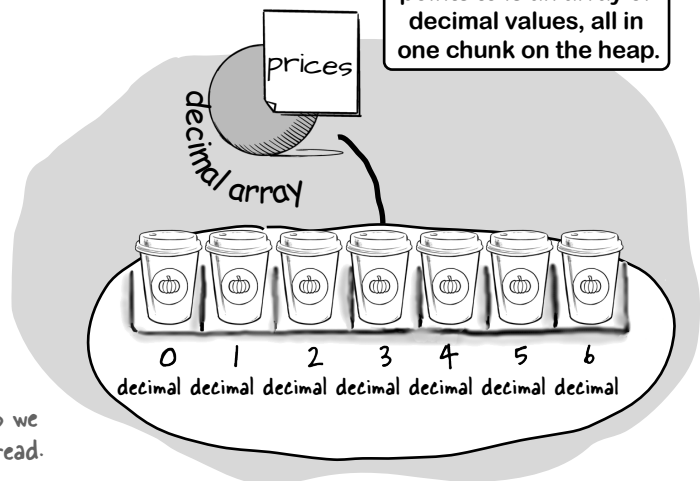
prices[3] = 1193.60M;
prices[4] = 58_000_000_000M;
prices[5] = 72.19M;
prices[6] = 74.8M;
```

C# ignores underscores in your number literals, so we used commas to make our long numbers easier to read.

We saw arrays of strings in Chapter 3. Now let's take a deeper dive into how arrays work.

You use the **new** keyword to create an array because it's an object—so an array variable is a kind of reference variable. In C#, arrays are **zero-based**, which means the first element has index 0.

The **prices** variable is a reference, just like any other object reference. The object it points to is an array of decimal values, all in one chunk on the heap.



Arrays can contain reference variables

You can create an **array of object references** just like you create an array of numbers or strings. Arrays don't care what type of variable they store; it's up to you. So you can have an array of ints, or an array of Duck objects, with no problem.

Here's code that creates an array of seven **Dog** variables. The line that initializes the array only creates reference variables. Since there are only two **new Dog()** lines, only two actual instances of the Dog class are created.

```
// Declare a variable that holds an
// array of references to Dog objects
Dog[] dogs = new Dog[7];

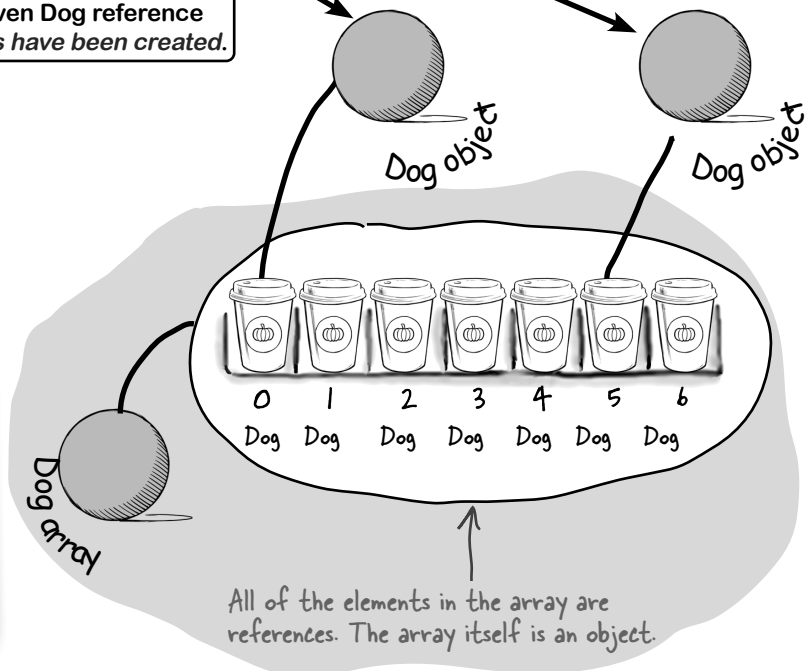
// Create two new instances of Dog
// and put them at indexes 0 and 5
dogs[5] = new Dog();
dogs[0] = new Dog();
```

When you set or retrieve an element from an array, the number inside the brackets is called the index. The first element in the array has an index of **0**.

The first line of code only created the array, not the instances. The array is a list of seven Dog reference variables—but only two Dog objects have been created.

An array's length

You can find out how many elements are in an array using its `Length` property. So if you've got an array called "prices," then you can use `prices.Length` to find out how long it is. If there are seven elements in the array, that gives you 7—which means the array elements are numbered 0 to 6.



“this” lets an object refer to itself

there are no Dumb Questions

Q: I'm still not sure I get how references work.

A: References are the way you use all of the methods and fields in an object. If you create a reference to a Dog object, you can then use that reference to access any methods you've created for the Dog object. If the Dog class has (nonstatic) methods called Bark and Fetch, you can create a reference called spot, and then you can use that to call spot.Bark() or spot.Fetch(). You can also change information in the fields for the object using the reference (so you could change a Breed field using spot.Breed).

Q: Then doesn't that mean that every time I change a value through a reference I'm changing it for all of the other references to that object too?

A: Yes. If the rover variable contains a reference to the same object as spot, changing rover.Breed to “beagle” would make it so that spot.Breed was “beagle.”

Q: Remind me again—what does this do?

A: `this` is a special variable that you can only use inside an object. When you're inside a class, you use `this` to refer to any field or method of that particular instance. It's especially useful when you're working with a class whose methods call other classes. One object can use it to send a reference to itself to another object. So if spot calls one of rover's methods passing `this` as a parameter, it's giving rover a reference to the spot object.

Any time you've got code in an object that's going to be instantiated, the instance can use the special “this” variable that has a reference to itself.

Q: You keep talking about garbage-collecting, but what's actually doing the collecting?

A: Every .NET app runs inside the **Common Language Runtime** (or the *Mono Runtime* if you're running your apps on macOS, Linux, Android, or iOS, basically anywhere other than Windows, or if you're using Mono on Windows—but it works the same way, so we'll just talk about the CLR in general here).

The CLR does a lot of stuff, but there are two *really important things* the CLR does that we're concerned about right now. First, it **executes your code**—specifically, the output produced by the C# compiler. Second, it manages the memory that your program uses. That means it keeps track of all of your objects, figures out when the last reference to an object disappears, and frees up the memory that it was using. The folks on the .NET team at Microsoft have done an enormous amount of work making sure that it's fast and efficient.

Q: I still don't get that stuff about different types holding different-sized values. Can you go over that one more time?

A: Sure. The thing about variables is they assign a size to your number no matter how big its value is. So if you name a variable and give it a long type even though the number is really small (like, say, 5), the CLR sets aside enough memory for it to get really big. When you think about it, that's really useful. After all, they're called “variables” because they change all the time.

The CLR assumes you know what you're doing and you're not going to give a variable a type bigger than it needs. So even though the number might not be big now, there's a chance that after some math happens, it'll change. The CLR gives it enough memory to handle the largest value that type can accommodate.

Sharpen your pencil

Here's an array of Elephant objects and a loop that will go through it and find the one with the biggest ears. What's the value of `biggestEars.EarSize` **after** each iteration of the `for` loop?

```
Elephant[] elephants = new Elephant[7];
elephants[0] = new Elephant() { Name = "Lloyd", EarSize = 40 };
elephants[1] = new Elephant() { Name = "Lucinda", EarSize = 33 };
elephants[2] = new Elephant() { Name = "Larry", EarSize = 42 };
elephants[3] = new Elephant() { Name = "Lucille", EarSize = 32 };
elephants[4] = new Elephant() { Name = "Lars", EarSize = 44 };
elephants[5] = new Elephant() { Name = "Linda", EarSize = 37 };
elephants[6] = new Elephant() { Name = "Humphrey", EarSize = 45 };
```

We're creating an array of seven Elephant references.

Arrays start with index 0, so the first Elephant in the array is `elephants[0]`.

```
Elephant biggestEars = elephants[0];
for (int i = 1; i < elephants.Length; i++)
{
    Console.WriteLine("Iteration #" + i);

    if (elephants[i].EarSize > biggestEars.EarSize)
    {
        biggestEars = elephants[i];
    }

    Console.WriteLine(biggestEars.EarSize.ToString());
}
```

Fill in these values.

Iteration #1 `biggestEars.EarSize` = _____

Iteration #2 `biggestEars.EarSize` = _____

Iteration #3 `biggestEars.EarSize` = _____

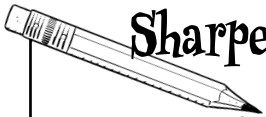
Iteration #4 `biggestEars.EarSize` = _____

Iteration #5 `biggestEars.EarSize` = _____

Iteration #6 `biggestEars.EarSize` = _____

Be careful—this loop starts with the second element of the array (at index 1) and iterates six times until "i" is equal to the length of the array.

This sets the `biggestEars` reference to the object that `elephants[i]` points to.



Sharpen your pencil Solution

Here's an array of Elephant objects and a loop that will go through it and find the one with the biggest ears. What's the value of `biggestEars.EarSize` **after** each iteration of the `for` loop?

The for loop starts with the second Elephant and compares it to whatever Elephant `biggestEars` points to. If its ears are bigger, it points `biggestEars` at that Elephant instead. Then it moves to the next one, then the next one...by the end of the loop, `biggestEars` points to the one with the biggest ears.

```
Elephant[] elephants = new Elephant[7];
elephants[0] = new Elephant() { Name = "Lloyd", EarSize = 40 };
elephants[1] = new Elephant() { Name = "Lucinda", EarSize = 33 };
elephants[2] = new Elephant() { Name = "Larry", EarSize = 42 };
elephants[3] = new Elephant() { Name = "Lucille", EarSize = 32 };
elephants[4] = new Elephant() { Name = "Lars", EarSize = 44 };
elephants[5] = new Elephant() { Name = "Linda", EarSize = 37 };
elephants[6] = new Elephant() { Name = "Humphrey", EarSize = 45 };
```

Did you remember that the loop starts with the second element of the array? Why do you think that is?

```
Elephant biggestEars = elephants[0];
for (int i = 1; i < elephants.Length; i++)
{
    Console.WriteLine("Iteration #" + i);

    if (elephants[i].EarSize > biggestEars.EarSize)
    {
        biggestEars = elephants[i];
    }
}
```

Iteration #1 `biggestEars.EarSize` = 40

Iteration #2 `biggestEars.EarSize` = 42

Iteration #3 `biggestEars.EarSize` = 42

Iteration #4 `biggestEars.EarSize` = 44

```
Console.WriteLine(biggestEars.EarSize.ToString());
}
```

The `biggestEars` reference keeps track of which Elephant we've seen so far has the biggest ears. Use the debugger to check this! Put your breakpoint here and watch `biggestEars.EarSize`.

Iteration #5 `biggestEars.EarSize` = 44

Iteration #6 `biggestEars.EarSize` = 45

null means a reference points to nothing

There's another important keyword that you'll use with objects. When you create a new reference and don't set it to anything, it has a value. It starts off set to **null**, which means **it's not pointing to any object at all**. Let's have a closer look at this:

The default value for any reference variable is null. Since we haven't assigned a value to `fido`, it's set to null.

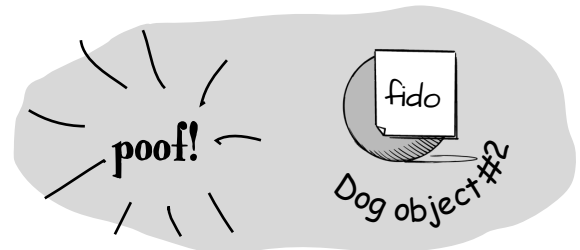
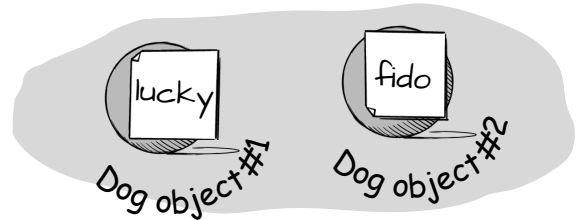
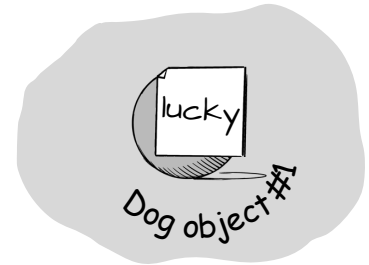
```
Dog fido;
Dog lucky = new Dog();
```

Now `fido` is set to a reference to another object, so it's not equal to null anymore.

```
fido = new Dog();
```

Once we set `lucky` to null it no longer points to its object, so it gets marked for garbage collection.

```
lucky = null;
```



Would I ever **really** use "null" in a program?

Yes. The null keyword can be useful.

There are a few ways you see **null** used in typical programs. The most common way is making sure a reference points to an object:

```
if (lloyd == null) {
```

That test will return **true** if the **lloyd** reference is set to **null**.

Another way you'll see the **null** keyword used is when you want your object to get garbage-collected. If you've got a reference to an object and you're finished with the object, setting the reference to **null** will immediately mark it for collection (unless there's another reference to it somewhere).




I think I've seen the word *null* before. Didn't the IDE tell me something about it when I was using `Console.ReadLine`?

Yes! `Console.ReadLine` can return a null value.

Back at the beginning of Chapter 3, you hovered over `Console.ReadLine` so you could learn more about it from the description that the IntelliSense quick info window showed you. Let's take another look at that window:

```
string? line = Console.ReadLine();
```

 `string? Console.ReadLine()`
Reads the next line of characters from the standard input stream.

Returns:
The next line of characters from the input stream, or null if no more lines are available.

Exceptions:
`IOException`
`OutOfMemoryException`
`ArgumentOutOfRangeException`

[GitHub Examples and Documentation](#)

Console.ReadLine will return the next line of characters that it reads. If there are no more lines, then it returns null.

Console.ReadLine returns a null when there are no lines available

You've been running your apps in Visual Studio and typing input using the keyboard. But you can also run them from the command line. In Windows, there's an executable in the `bin\Debug` folder. You can use this command to run your app from the project folder:

```
C:\Users\Public\source\repos\ConsoleApp1\ConsoleApp1>dotnet run  
Hello, World!
```

You can also use your operating system's pipe commands like `<<` or `<` or `|` to send input to your app from a file or the output of another console app. When you do this, `Console.ReadLine` needs a way to tell your app that it hit the end of the file—and that's when it returns null.

But there's still one issue: *what does your app do when `Console.ReadLine` returns null?*

Make sure you run from inside the project folder that has the .csproj file, not the solution folder that contains it.

Use the string? type when a string might be null

You've been using two different (but related!) types to hold text values. First, there's the `string` type, like you used for the `Name` field in the `Elephant` class:

```
public string Name = "";
```

Then there's the `string?` type, like the type returned by `Console.ReadLine` or which `int.TryParse` takes as its first parameter, like you used in Owen's ability score calculator app:

```
string? line = Console.ReadLine();
if (int.TryParse(line, out int value))
```

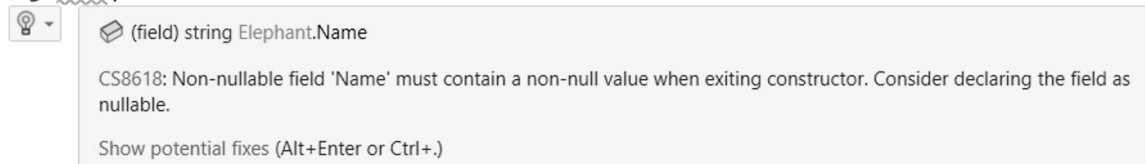
The difference is that in the `Elephant` class *the `Name` field is never null*. That's why we asked you to initialize the `Name` field in your `Elephant` class.

What do you think would happen if you didn't initialize the `Name` field in the `Elephant` class?

← Do this!

Change the field declaration in the `Elephant` class so it doesn't initialize it to an empty string:

```
public string Name;
```



Visual Studio gives you a warning that has to do with null values, and asks you to consider declaring the field as nullable. That's what the `string?` type is—a **nullable string**.

You can make the error disappear by changing the `Name` field to a nullable `string?` instead of a `string`:

```
public string? Name;
```

Now your app builds again, and runs exactly the same way as it did before.

`int.TryParse` takes a `string?` parameter

So what does your app do if `Console.ReadLine` returns null?

Luckily, `int.TryParse` also takes a `string?` value, so if your app gets to the end of the input and `Console.ReadLine` returns null, `int.TryParse` will just return false—so the app will work just fine, and when it gets a null value it will treat it the way it treats any other value that can't be parsed.

Use the debugger to step through the app, and add a watch for the holder variable. Its value is null until it runs this statement: `holder = lloyd;`

Visual Studio is smart enough to check for possible places where a value can be null. You can avoid that problem by making sure all of your reference variables are initialized.



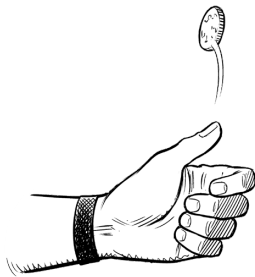
Tabletop Games

There's a rich history to tabletop games—and, as it turns out, a long history of tabletop games influencing video games, at least as early as the very first commercial role-playing game.

- The first edition of Dungeons and Dragons (D&D) was released in 1974, and that same year games with names like “dungeon” and “dnd” started popping up on university mainframe computers.
- You've used the Random class to create numbers. The idea of games based on random numbers has a long history—for example, tabletop games that use dice, cards, spinners, and other sources of randomness.
- We saw in Chapter 3 how a paper prototype can be a valuable first step in designing a video game. Paper prototypes have a strong resemblance to tabletop games. In fact, you can often turn the paper prototype of a video game into a playable tabletop game, and use it to test some game mechanics.
- You can use tabletop games—especially card games and board games—as learning tools to understand the more general concept of game mechanics. Dealing, shuffling, dice rolling, rules for moving pieces around the board, use of a sand timer, and rules for cooperative play are all examples of mechanics.
- The mechanics of Go Fish include dealing cards, asking another player for a card, saying “Go Fish” when asked for a card you don't have, determining the winner, etc. We're going to actually build a Go Fish game later in the book, so take a minute and read the rules:

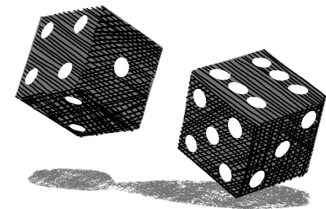
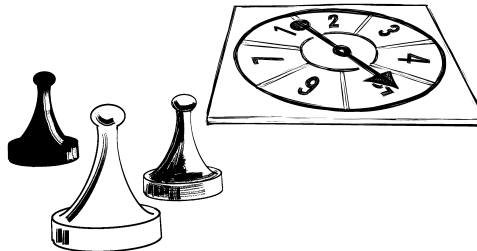
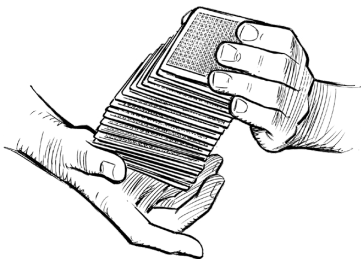
https://en.wikipedia.org/wiki/Go_Fish#The_game.

If you've never played Go Fish, take a few minutes and read the rules. We'll use them later in the book!



Even if we're not writing code for video games, there's a lot we can learn from tabletop games.

A lot of our programs depend on **random numbers**. For example, you've already used the Random class to create random numbers for several of your apps. Most of us don't actually have a lot of real-world experience with genuine random numbers... except when we play games. Rolling dice, shuffling cards, spinning spinners, flipping coins...these are all great examples of **random number generators**. The Random class is .NET's random number generator—you'll use it in many of your programs, and your experience using random numbers when playing tabletop games will make it a lot easier for you to understand what it does.





A Random Test Drive

You'll be using the **Random class** throughout the book, so let's get to know it better by kicking its tires and taking it for a spin. Fire up Visual Studio and follow along—and make sure you run your code multiple times, since you'll get different random numbers each time.

- 1 **Create a new console app**—all of this code will go in the top-level statements. **Random.Shared** returns an **instance of the Random class**. Start by using it to generate a random int:

```
int randomInt = Random.Shared.Next();
Console.WriteLine(randomInt);
```

Specify a **maximum value** to get random numbers from 0 up to—but not including—the maximum value. A maximum of 10 generates random numbers from 0 to 9:

```
int zeroToNine = Random.Shared.Next(10);
Console.WriteLine(zeroToNine);
```

- 2 Now **simulate the roll of a die**. You can specify a minimum and maximum value. A minimum of 1 and maximum of 7 generates random numbers from 1 to 6:

```
int dieRoll = Random.Shared.Next(1, 7);
Console.WriteLine(dieRoll);
```

- 3 The **NextDouble method** generates random double values. Hover over the method name to see a tooltip—it generates a floating-point number from 0.0 up to 1.0:

```
double randomDouble = Random.Shared.NextDouble();
```

```
double Random.NextDouble()
Returns a random floating-point number that is greater than or equal to 0.0, and less than 1.0.
```

You can **multiply a random double** to generate much larger random double values. So if you want a random double value from 1 to 100, multiply the random double by 100:

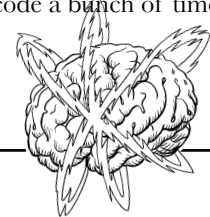
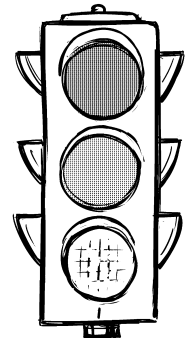
```
Console.WriteLine(randomDouble * 100);
```

Use **casting** to convert the random double to other types. Try running this code a bunch of times—you'll see tiny precision differences in the float and decimal values.

```
Console.WriteLine((float)randomDouble * 100F);
Console.WriteLine((decimal)randomDouble * 100M);
```

- 4 Use a maximum value of 2 to **simulate a coin toss**. That generates a random value of either 0 or 1. Use the **Convert class**, which has a static **ToBoolean** method that will convert it to a Boolean value:

```
int zeroOrOne = Random.Shared.Next(2);
bool coinFlip = Convert.ToBoolean(zeroOrOne);
Console.WriteLine(coinFlip);
```



Brain Power

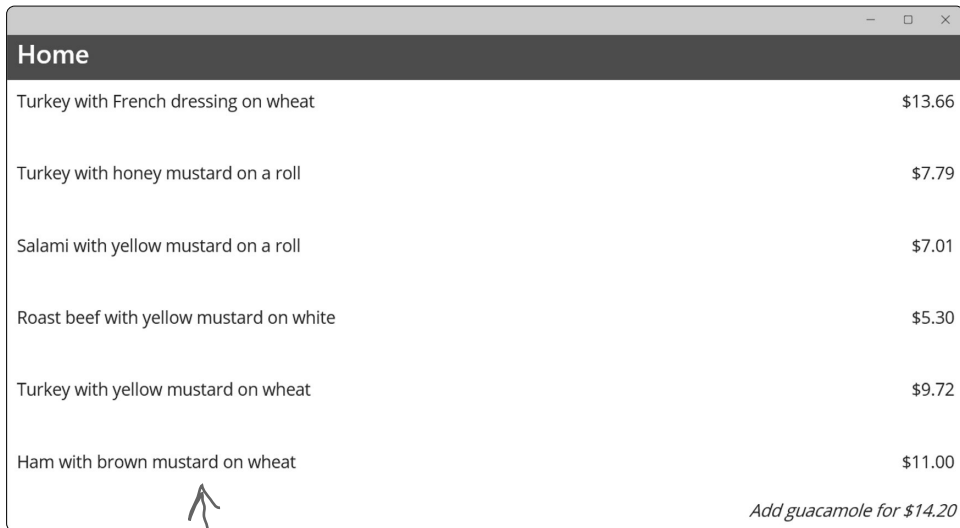
How would you use Random to choose a random string from an array of strings?

Welcome to Sloppy Joe's Budget House o' Discount Sandwiches!

Sloppy Joe has a pile of meat, a whole lotta bread, and more condiments than you can shake a stick at. What he doesn't have is a menu! Can you build a program that makes a new random menu for him every day? You definitely can...with a **new MAUI app**, some arrays, your handy random number generator, and a couple of new, useful tools. Let's get started!

Here's the app you'll build. It creates a menu with six random sandwiches. Each sandwich has a protein, a condiment, and a bread, all chosen at random from a list. Every sandwich is given a random price, and there's a special random price at the bottom to add guacamole on the side.

Sloppy Joe needs a new menu every day. Your app will generate random sandwiches and prices for him.



Home	
Turkey with French dressing on wheat	\$13.66
Turkey with honey mustard on a roll	\$7.79
Salami with yellow mustard on a roll	\$7.01
Roast beef with yellow mustard on white	\$5.30
Turkey with yellow mustard on wheat	\$9.72
Ham with brown mustard on wheat	\$11.00
Add guacamole for \$14.20	

Each sandwich is generated by choosing a random protein, random condiment, and random bread from arrays.

The prices are random numbers between 5.00 and 14.99.



Sloppy Joe's menu app uses a Grid layout

A **Grid control** contains other controls, and defines a set of rows and columns to lay out those controls.

You've used other layout controls: you've used `VerticalStackLayout` controls to stack `Button`, `Label`, and other controls in your apps on top of each other. You used a `HorizontalStackLayout` control in Chapter 2 for your bird picker. And in the Animal Matching Game project, your `VerticalStackLayout` contained a `FlexLayout` that arranged the buttons so they stacked horizontally, flowing into rows as the window size changed.

Here's an example of a Grid layout with two rows and three columns.

The layout adjusts as you change the window size.

This cell spans the first two columns, which means that it takes up the full width of both of them combined.

The first column is twice as wide as the second.

The second column.

The third column is 1.5 times as wide as the second.

The Grid preserves the row and column proportions when you change the size and shape of the page, which is really useful when you want your app to run on devices with different screen sizes.



Watch it!

A Grid control is for *layouts*, not data.

When most of us see something that contains “rows” and “columns,” we think of tables of data, like spreadsheets or HTML tables. That’s not what a Grid control is all about.

The Grid control is for **laying out content**. Its job is to contain other controls, and give you a way to design more interesting or intricate layouts than you get with stack panels, in a way that works well with different window sizes or on mobile devices.

Grid controls

The Grid control contains other controls, and works just like the other layout controls to contain **child controls** (the other controls nested inside it). There's an opening `<Grid>` tag and a closing `</Grid>` tag, and the tags for all of the child controls are between them.

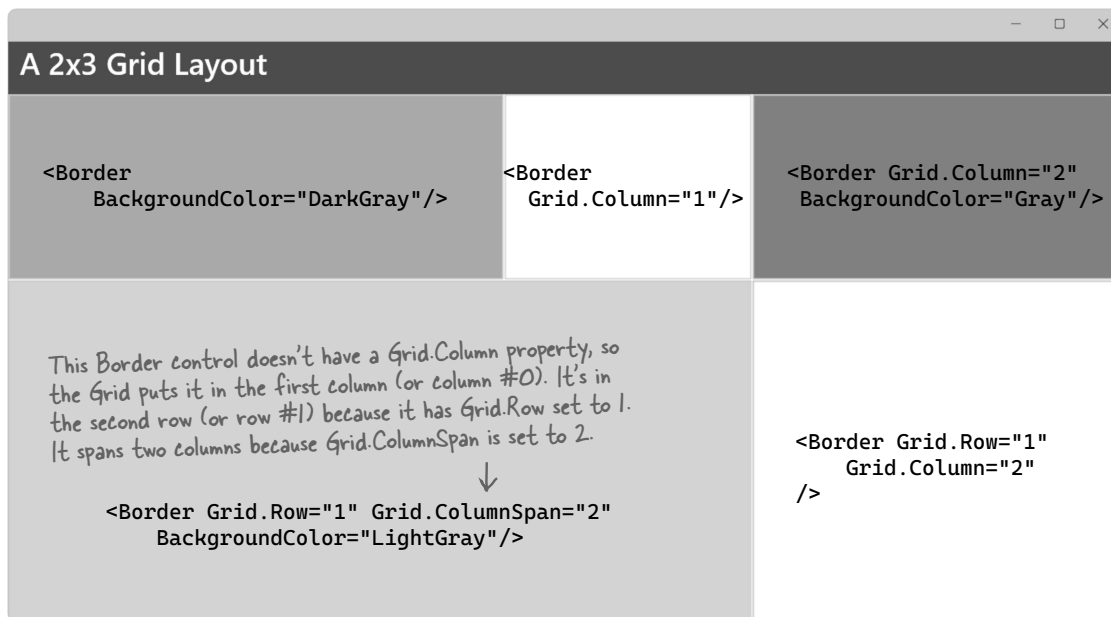
Cells in a grid are invisible—their only purpose is to determine where the child controls are displayed on the page. We used **Border controls** to make the grid visible. A Border control draws a border around a child control nested inside it:

```
<Border>
  <Label Text="I have a border!" />
</Border>
```

A Border can only contain one child control. In the app below we didn't nest any controls inside the Borders—we just took advantage of the fact that each Border fills up the entire cell. We used the Border control's `BackgroundColor` property to make some of the cells in the grid darker.

Use Grid properties to put a control in a cell

The rows and columns in a Grid are numbered starting with 0. To put a child control in a specific row and column, use the `Grid.Row` and `Grid.Column` properties. For example, putting `<Border Grid.Row="1" Grid.Column="2" />` between Grid tags will make the Grid place the border in the second row and third column. You can also make a control span multiple rows or columns using the `Grid.RowSpan` and `Grid.ColumnSpan` properties.



Define the rows and columns for a Grid

The Grid control XAML has sections to define rows and columns. Each row or column can either have proportional sizes—for example, column 3 is twice as wide as column 2 and three times as wide as column 1—or absolute sizes in device-independent pixels.

The row and column definitions are in special sections inside the `<Grid>` tag. The row definitions are inside a `<Grid.RowDefinitions>` section, and the column definitions are inside a `<Grid.ColumnDefinitions>` section.

Here's the complete XAML for the app that we've been showing you. **Create a .NET MAUI app** called `GridExample` and add this XAML code (and delete the `OnCounterClicked` method in `MainPage.xaml.cs`).

```
<?xml version="1.0" encoding="utf-8" ?>
<ContentPage xmlns="http://schemas.microsoft.com/dotnet/2021/maui"
  xmlns:x="http://schemas.microsoft.com/winfx/2009/xaml"
  x:Class="GridExample.MainPage">
```

← Do this!

```
<ScrollView>
```

```
<Grid>
```

```
<Grid.RowDefinitions>
  <RowDefinition/>
  <RowDefinition Height="2*" />
</Grid.RowDefinitions>
```

The app has two rows, so the `Grid.RowDefinitions` section contains two `RowDefinition` tags. The second row height is twice as tall as the first row, so we added the `Height="2*"` property to the second `RowDefinition` tag to make it twice as tall.

```
<Grid.ColumnDefinitions>
  <ColumnDefinition Width="2*" />
  <ColumnDefinition />
  <ColumnDefinition Width="1.5*" />
</Grid.ColumnDefinitions>
```

The `Grid.ColumnDefinitions` section has three `ColumnDefinition` tags, one for each of the three columns. The first column is twice as wide as the second, so it has `Width="2*"`. The third column is 1.5 times as wide, so it has `Width="1.5*"`.

Here are the child `Border` controls we just showed you.

```
<Border BackgroundColor="DarkGray" />
<Border Grid.Column="1" />
<Border Grid.Column="2" BackgroundColor="Gray" />

<Border Grid.Row="1" Grid.ColumnSpan="2" BackgroundColor="LightGray" />
<Border Grid.Row="1" Grid.Column="2" />
```

```
</Grid>
```

```
</ScrollView>
```

```
</ContentPage>
```

Row heights and column widths

When you use a value like `2*` in a `RowDefinition.Height` or `ColumnDefinition.Width` property, you're choosing a proportional width, which means they're proportional to each other. You'll get the same results setting the first row to `6*` and the second row to `12*` because the proportions are still the same: the second row is still twice as big as the first row.

You can also set a row width or column height to an absolute value like `100`, which will cause it to be sized in device-independent pixels. If all the rows and columns are proportional, the grid will fill up the page. If you set an absolute width or height, it could end up larger than the page, which is why it's a good idea to nest the `Grid` inside a `ScrollView`.

start building the app for sloppy joe

Create the Sloppy Joe's menu app and set up the grid

Create a new **.NET MAUI app** and name it SloppyJoe. The first thing you'll do is create the XAML for the app. Here's how it will work:

```
<ContentPage>  
  <ScrollView>  
    <Grid Margin="10">
```

The grid has two columns. Column 1 is 5 times wider than column 2.

Welcome to Sloppy Joe's	
item #1	price #1
item #2	price #2
item #3	price #3
item #4	price #4
item #5	price #5
item #6	price #6
guacamole	

The grid has seven equal-sized rows

```
  </Grid>  
  </ScrollView>  
</ContentPage>
```

Each of the cells in the grid contains a Label control...

...except for the Label with the guacamole price, which fills up the whole row by spanning two cells.

We'll give you all of the XAML for the app. But before we do, try editing the *MainPage.xaml* file and creating the XAML for the page on your own. Can you use the app we just gave you as an example to create the row and column definitions yourself?

See how far you can get, then compare it with our XAML.

Here's the XAML for the app

Take your time and go through it line by line to make sure you understand how its grid works.

```

<?xml version="1.0" encoding="utf-8" ?>
<ContentPage xmlns="http://schemas.microsoft.com/dotnet/2021/maui"
  xmlns:x="http://schemas.microsoft.com/winfx/2009/xaml"
  x:Class="SloppyJoe.MainPage">
  <ScrollView>
    <Grid Margin="10">
      <Grid.RowDefinitions>
        <RowDefinition/>
        <RowDefinition/>
        <RowDefinition/>
        <RowDefinition/>
        <RowDefinition/>
        <RowDefinition/>
      </Grid.RowDefinitions>
      <Grid.ColumnDefinitions>
        <ColumnDefinition Width="5*"/>
        <ColumnDefinition/>
      </Grid.ColumnDefinitions>
      <Label x:Name="item1" FontSize="18" Text="item #1" />
      <Label x:Name="price1" FontSize="18" HorizontalOptions="End"
        Grid.Column="1" Text="price #1"/>
      <Label x:Name="item2" FontSize="18" Grid.Row="1" Text="item #2"/>
      <Label x:Name="price2" FontSize="18" HorizontalOptions="End"
        Grid.Row="1" Grid.Column="1" Text="price #2"/>
      <Label x:Name="item3" FontSize="18" Grid.Row="2" Text="item #3" />
      <Label x:Name="price3" FontSize="18" HorizontalOptions="End"
        Grid.Row="2" Grid.Column="1" Text="price #3"/>
      <Label x:Name="item4" FontSize="18" Grid.Row="3" Text="item #4" />
      <Label x:Name="price4" FontSize="18" HorizontalOptions="End"
        Grid.Row="3" Grid.Column="1" Text="price #4"/>
      <Label x:Name="item5" FontSize="18" Grid.Row="4" Text="item #5" />
      <Label x:Name="price5" FontSize="18" HorizontalOptions="End"
        Grid.Row="4" Grid.Column="1" Text="price #5"/>
      <Label x:Name="item6" FontSize="18" Grid.Row="5" Text="item #6" />
      <Label x:Name="price6" FontSize="18" HorizontalOptions="End"
        Grid.Row="5" Grid.Column="1" Text="price #6"/>
      <Label x:Name="guacamole" FontSize="18" FontAttributes="Italic" Text="guacamole"
        Grid.Row="6" Grid.ColumnSpan="2" HorizontalOptions="End" VerticalOptions="End" />
    </Grid>
  </ScrollView>
</ContentPage>

```

If you used a different app name, you'll see a different namespace here.

The 10-pixel margin around the grid adds a little space between the Labels and the edge of the window.

The grid has six rows that are all the same height.

The grid has two columns. The first column is five times wider than the second.

After you add this code to your **MainPage.xaml** file, don't forget to go to the **MainPage.xaml.cs** file and delete the **OnCounterClicked** method and count field.

Each of these Label controls goes in a different cell. We gave each of them text like "item #1" or "price #3" to make it easier to see how the grid is laid out when you run the app.

Each price has its **HorizontalOptions** set to "End" so it gets aligned all the way to the right of the window.

This Label spans both columns in the bottom row, so it stretches across two cells. Try removing the **Grid.ColumnSpan** property—what happens?

The Label with the guacamole price has both its **Horizontal** and **Vertical** options set to "End" to align it to the bottom right corner of the cell.

The C# code for the main page

Here's the C# code for the main page of your Sloppy Joe app. We're about to give you an exercise to build a class called MenuItem that generates random sandwiches and prices. As soon as the page loads, it calls a method called MakeTheMenu that uses an array of MenuItem objects to fill in all of the prices, and one last MenuItem object to get the price for the guacamole.

```
namespace SloppyJoe;  Your namespace will be different if you chose a different name for your app.
```

```
public partial class MainPage : ContentPage  
{  
    public MainPage()  
    {  
        InitializeComponent();  
        MakeTheMenu();  Call the MakeTheMenu method as soon as the page loads.  
    }  
  
    private void MakeTheMenu()  
    {  
        MenuItem[] menuItem = new MenuItem[6];  This array will hold six references to MenuItem objects.  
  
        for (int i = 0; i < 6; i++)  
        {  
            menuItem[i] = new MenuItem();  
            menuItem[i].Generate();  
        }  You'll use a for loop to create each MenuItem and call its Generate method. You'll write that Generate method in the next exercise.  
  
        price1.Text = menuItem[0].Price;  
        item1.Text = menuItem[0].Description;  
        price2.Text = menuItem[1].Price;  
        item2.Text = menuItem[1].Description;  
        price3.Text = menuItem[2].Price;  
        item3.Text = menuItem[2].Description;  
        price4.Text = menuItem[3].Price;  
        item4.Text = menuItem[3].Description;  
        price5.Text = menuItem[4].Price;  
        item5.Text = menuItem[4].Description;  
        price6.Text = menuItem[5].Price;  
        item6.Text = menuItem[5].Description;  
    }  Now that you have the MenuItem objects with sandwich descriptions and prices, you can use them to set the text in the Label controls.  
  
    MenuItem guacamoleMenuItem = new MenuItem();  
    guacamoleMenuItem.Generate();  
    guacamole.Text = "Add guacamole for " + guacamoleMenuItem.Price;  
}  
}
```

 Create one more MenuItem object to generate a random price for the guacamole. You won't use its Description field.

Exercise

Create the MenuItem class for your menu app.

Start by looking closely at the class diagram. It has five fields: three arrays to hold the various sandwich parts, a description, and a price. The array fields use **collection expressions** that let you create an array by putting comma-separated values between [square brackets].

Add the MenuItem class to your project. Here's the code for the fields:

```
namespace SloppyJoe;
```

```
class MenuItem
{
```

```
    public string[] Proteins = [
        "Roast beef", "Salami", "Turkey",
        "Ham", "Pastrami", "Tofu"
    ];
```

```
    public string[] Condiments = [
        "yellow mustard", "brown mustard",
        "honey mustard", "mayo", "relish", "French dressing"
    ];
```

```
    public string[] Breads = [ "rye", "white", "wheat", "pumpernickel", "a roll" ];
```

```
    public string Description = "";
    public string Price = "";
```

```
    public void Generate()
    {
        // You'll fill in this method
    }
}
```

The MenuItem class has three array fields that use collection expressions to set their values, just like the array you saw in Chapter 3 to store playing cards.

The Generate method uses Random.Shared to choose random prices between 5.00 and 14.99 by creating a random decimal value out of two ints. We gave you the last line of code for the method:

```
Price = price.ToString("c");
```

The parameter to the ToString method is a format. In this case, the "c" format tells ToString to format the value with the local currency: if you're in the United States you'll see a \$, in the UK you'll get a £, in the EU you'll see €, etc. If the values don't make sense in your currency, choose different random numbers!

Your job is to fill in the Generate method. It does the following:

- Picks a random protein from the Proteins array.
- Picks a random condiment from the Condiments array.
- Picks a random bread from the Breads array.
- Sets the description field like this: `protein + " with " + condiment + " on " + bread`.
- Sets the Price field to a random price that's at least 5.00 and less than 15.00. Pick a random int that's at least 5 and less than 15. Then pick a second random int that's at least 0 and less than 100. Multiply the second number by .01M to get a decimal value that's at least .00 and less than 1.00, and add it to the first value, and store it in a variable called `price`. Then set the Price field like this: `Price = price.ToString("c");`



Sharpen your pencil

Can you write a single line of code that sets Price to a random value between 5.00 and 14.99? Here's a hint: if the NextDouble method returns a value between 0 and 1, try multiplying it by 10. What do you get?

.....

MenuItem

Proteins
Condiments
Breads
Description
Price

Generate

Exercise Solution

```
public void Generate()
{
    string protein = Proteins[Random.Shared.Next(Proteins.Length)];
    string condiment = Condiments[Random.Shared.Next(Condiments.Length)];
    string bread = Breads[Random.Shared.Next(Breads.Length)];
    Description = protein + " with " + condiment + " on " + bread;

    int bucks = Random.Shared.Next(5, 15);
    int cents = Random.Shared.Next(0, 100);
    decimal price = bucks + (cents * .01M);
    Price = price.ToString("c");
}
```

Can you write a single line of code that sets Price to a random value between 5.00 and 14.99? Here's a hint: if the NextDouble method returns a value between 0 and 1, try multiplying it by 10. What do you get?

```
Price = (Random.Shared.NextDouble() * 10 + 5).ToString("c");
```




We haven't talked about **accessibility** in this project yet. Shouldn't we add semantic properties to the controls in the menu app?

You're right! This is a great time to improve accessibility.





Sloppy Joe has a wheelchair ramp and braille versions of all of his menus, because he wants to make sure everyone has a chance to eat his budget-friendly sandwiches. So let's make sure our menu app is accessible too!

Start your operating system's screen reader and read the menu page.

Windows Narrator

Start Windows Narrator (Ctrl++N). Narrator will scroll through the contents of any window when you hold down the Narrator key (typically the Insert key, but you can change that in Narrator settings) and press the left or right arrows. Navigate to your app, then navigate through all the controls and listen to what Narrator says.

macOS VoiceOver

Start VoiceOver (+F5). VoiceOver will read the contents of any window when you hold down the VoiceOver activation key (^ control +  option) and press A. Navigate to your app and press VO+A (or ^ A), and listen to what VoiceOver says. Press the either ^ or  to stop reading.

 **Do this!**

Can we make the app more accessible?

When a screen reader narrates a window, it navigates from item to item, reading each item aloud and drawing a rectangle around it. What did you hear when you listened to the screen reader narrate your app? What did you see? Try having it read the menu while you have your eyes closed. Did you still understand everything that you needed to? It's pretty good! But accessibility is all about making things better for all of our users. Can we make it better?

Set the main header so the screen reader narrates it

You may have noticed that the first thing it said was “Home”—and if you watched carefully, you saw that was narrating the title bar. **Modify *AppShell.xaml* to change “Home” to “Sloppy Joe’s menu”** and have the screen reader narrate the page again.

It would be great to have the narrator tell the user that they’re looking at items on a menu. Let’s try adding a `SemanticProperties.Description` to the `<Grid>` tag:

```
<Grid Margin="10"
      SemanticProperties.Description="Here are the items on the menu.">
```

Now try using the screen reader to narrate the window. It sounds fine in Windows, but if you’re using macOS there’s a problem: the screen reader won’t read the items or prices. That’s because if you set the `SemanticProperties.Description` on a control that has children, the screen reader can’t reach those children anymore. This is important even if you’re building software for Windows, because your MAUI apps are cross-platform, and you want your app to be accessible anywhere.

Try setting the `item1` label’s `SemanticProperties.Description` instead

OK, let’s try something else. Remove the `SemanticProperties.Description` property from the `<Grid>` tag. Then try setting the `SemanticProperties.Description` on the first label:

```
<Label x:Name="item1" FontSize="18" Text="item #1"
      SemanticProperties.Description="Here are the items on the menu." />
```

Try using the screen reader again. ***It’s still not right!*** When you have a `Label`, you always want the screen reader to read the contents of the label. Setting the `SemanticProperties.Description` causes the screen reader to read that description *instead of the label text*.

Go ahead and delete the `SemanticDescription` property from the `item1` `Label` control (and also from the `Grid`, if you haven’t done it already).



Brain Power

What do you think you’ll do to make the screen reader say “Here are the items on the menu” followed by the randomly generated sandwich in the `item1` `Label` control’s `Text` property?

Use the SetValue method to change a control's semantic properties

Let's find a different way to make the screen reader say "Here are the items on the menu" before it reads the menu items. We'll still use the `SemanticProperties.Description` for the first menu item, but instead of using a XAML tag, we'll use C# to make sure it preserves the text.

Add this line of code to the end of your `MainPage` method:

```
public MainPage()
{
    InitializeComponent();
    MakeTheMenu();

    item1.SetValue(SemanticProperties.DescriptionProperty,
"Here are the items on the menu. " + item1.Text);
}
```

If you type "item1." into Visual Studio, you won't see `SemanticProperties` in the IntelliSense pop-up. That's why you need to use the `SetValue` method to set it instead.

This code sets the `SemanticProperties.Description` property—in this case, it's setting it to the text "Here are the items on the menu" followed by the random sandwich generated by `MenuItem`. Try the screen reader one more time—now the page includes that text, and works on all operating systems.

Bullet Points

- The **new keyword** returns a reference to an object that you can store in a reference variable.
- You can have **multiple references** to the same object. You can change an object with one reference and access the results of that change with another.
- For an object to stay in the heap, it **has to be referenced**. Once the last reference to an object disappears, it eventually gets **garbage-collected** and the memory it used is reclaimed.
- Your .NET apps run in the **Common Language Runtime (CLR)**, a "layer" between the OS and your program. The C# compiler builds your code into **Common Intermediate Language (CIL)**, which the CLR executes.
- Declare **array variables** by putting square brackets after the type in the variable declaration (like `bool[] trueFalseValues` or `Dog[] kennel`).
- Use the **new keyword to create a new array**, specifying the array length in square brackets (like `new bool[15]` or `new Dog[3]`). The **this keyword** lets an object get a reference to itself.
- An AI chatbot can read your code and **add comments**, including XML documentation (XMLDoc) comments.
- Use the **Length method** on an array to get its length (like `kennel.Length`).
- Access an array value using its **index** in square brackets (like `bool[3]` or `Dog[0]`). Array indexes **start at 0**.
- null means a reference **points to nothing**. The compiler will warn you when a variable can **potentially be null**.
- Use the **string? type** to hold a string that's allowed to be null. `Console.ReadLine` can return null strings.
- You can use **Random.NextDouble** to create a random double value between 0 and 1. Multiply a random double to generate much larger random double values.
- Use **collection expressions** to initialize an array field by setting the field equal to a value starting with a square bracket, followed by a comma-delimited list of values, and ending with a square bracket.
- You can pass a **format parameter** to an object or value's `ToString` method. If you're calling a numeric type's `ToString` method, passing it a value of "c" formats the value as a local currency.
- Use a control's **SetValue method** to set its semantic properties in code, so the screen reader can include text that's generated when the app runs.

Unity Lab #2

Write C# Code for Unity

Unity isn't *just* a powerful, cross-platform engine and editor for building 2D and 3D games and simulations. It's also a **great way to get practice writing C# code.**

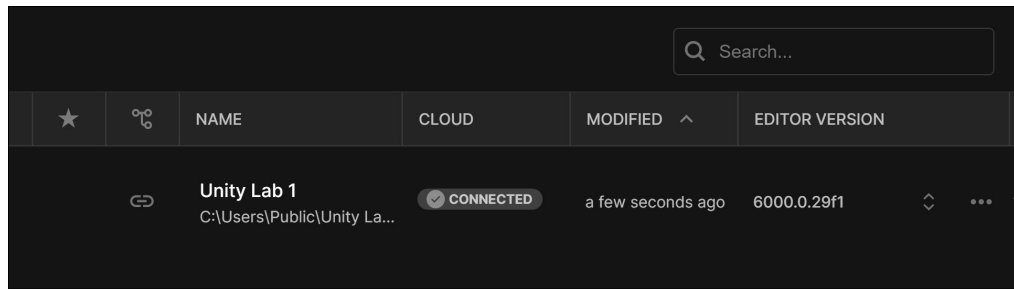
In the last Unity Lab, you learned how to navigate around Unity and your 3D space, and started to create and explore GameObjects. Now it's time to write some code to take control of your GameObjects. The whole goal of that lab was to get you oriented in the Unity editor (and give you an easy way to remind yourself of how to navigate around it if you need it).

In this Unity Lab, you'll start writing code to control your GameObjects. You'll write C# code to explore concepts you'll use in the rest of the Unity Labs, starting with adding a method that rotates the 8 Ball GameObject that you created in the last Unity Lab. You'll also start using the Visual Studio debugger with Unity to sleuth out problems in your games.

C# scripts add behavior to your GameObjects

Now that you can add a GameObject to your scene, you need a way to make it, well, do stuff. That's where your C# skills come in. Unity uses **C# scripts** to define the behavior of everything in the game.

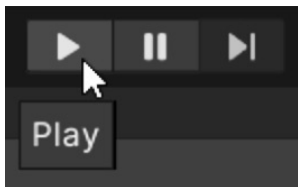
This Unity Lab will introduce tools that you'll use to work with C# and Unity. You're going to build a simple "game" that's really just a little bit of visual eye candy: you'll make your 8 ball fly around the scene. Start by going to Unity Hub and **opening the same project** that you created in the first Unity Lab.



This Unity Lab picks up where the first one left off, so go to Unity Hub and open the project you created in the last lab.

Here's what you'll do in this Unity Lab:

- 1 Attach a C# script to your GameObject.** You'll add a Script component to your Sphere GameObject. When you add it, Unity will create a class for you. You'll modify that class so that it drives the 8 ball sphere's behavior.
- 2 Use Visual Studio to edit the script.** Remember how you set the Unity editor's preferences to make Visual Studio the script editor? That means you can just double-click on the script in the Unity editor and it will open up in Visual Studio.
- 3 Play your game in Unity.** There's a Play button at the top of the screen. When you press it, it starts executing all of the scripts attached to the GameObjects in your scene. You'll use that button to run the script that you added to the sphere.



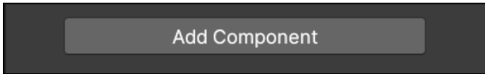
← The Play button does not save your game! So make sure you save early and save often. A lot of people get in the habit of saving the scene every time they run the game.

- 4 Use Unity and Visual Studio together to debug your script.** You've already seen how valuable the Visual Studio debugger is when you're trying to track down problems in your C# code. Unity and Visual Studio work together seamlessly so you can add breakpoints, use the Locals window, and work with the other familiar tools in the Visual Studio debugger while your game is running.

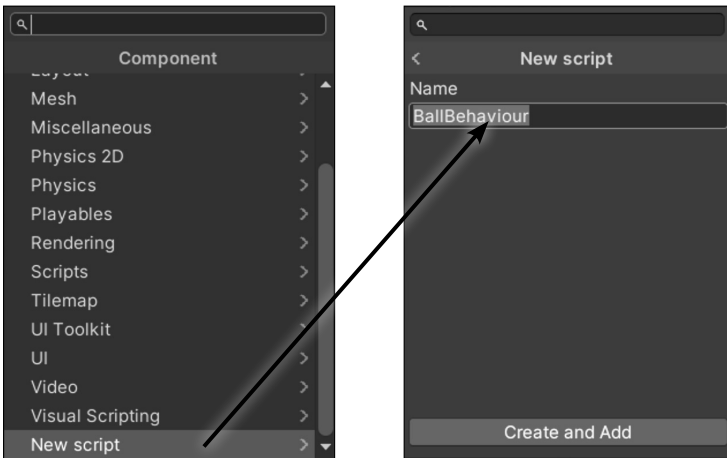
Add a C# script to your GameObject

Unity is more than an amazing platform for building 2D and 3D games. Many people use it for artistic work, data visualization, augmented reality, and more. It's especially valuable to you, as a C# learner, because you can write code to control everything that you see in a Unity game. That makes Unity *a great tool for learning and exploring C#*.

Let's start using C# and Unity right now. Make sure the Sphere GameObject is selected, then **click the Add Component button** at the bottom of the Inspector window.



When you click it, Unity pops up a window with all of the different kinds of components that you can add—and there are *a lot* of them. **Choose “New script”** to add a new C# script to your Sphere GameObject. You'll be prompted for a name. **Name your script** BallBehaviour.

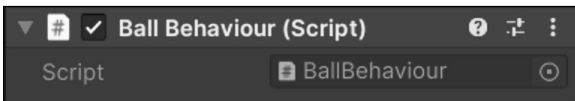


Watch it!

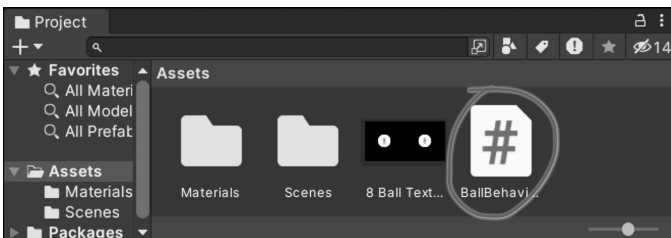
Unity code uses British spelling.

*If you're American (like us), or if you're used to the US spelling of the word **behavior**, you'll need to be careful when you work with Unity scripts because the class names often feature the British spelling **behaviour**.*

Click the “Create and Add” button to add the script. You'll see a component called *Ball Behaviour (Script)* appear in the Inspector window.



You'll also see the C# script in the Project window.



The *Project window* gives you a folder-based view of your project. Your Unity project is made up of files: media files, data files, C# scripts, textures, and more. Unity calls these files *assets*. The *Project window* was displaying a folder called *Assets* when you right-clicked inside it to import your texture, so Unity added it to that folder.

Did you notice a folder called *Materials* appeared in the *Project window* as soon as you dragged the *8 ball texture* onto your sphere?

Write C# code to rotate your sphere

In the first lab, you told Unity to use Visual Studio as its external script editor. So go ahead and **double-click your new C# script in the Assets window**. When you do, **Unity will open your script in Visual Studio**. Your C# script contains a class called BallBehaviour with two empty methods called Start and Update:

```
using UnityEngine;

public class BallBehaviour : MonoBehaviour
{
    // Start is called before the first frame update
    void Start()
    {

    }

    // Update is called once per frame
    void Update()
    {

    }
}
```

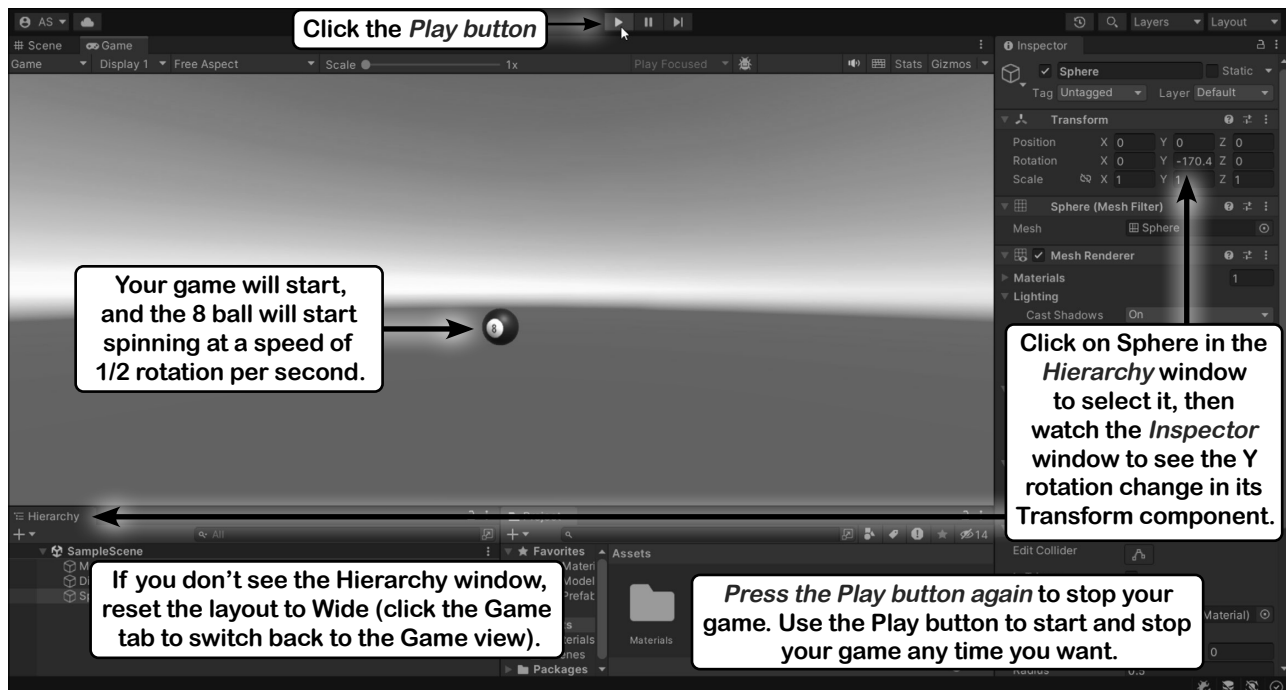
You opened your C# script in Visual Studio by clicking on it in the Hierarchy window, which shows you a list of every GameObject in the current scene. When Unity created your project, it added a scene called SampleScene with a camera and a light. You added a sphere to it, so your Hierarchy window will show all of those things.

If Unity didn't launch Visual Studio and open your C# script in it, go back to the beginning of Unity Lab 1 and make sure you followed the steps to set the External Tools preferences.

Here's a line of code that will rotate your sphere. **Add it to your Update method:**

```
transform.Rotate(Vector3.up, 180 * Time.deltaTime);
```

Now **go back to the Unity editor** and click the Play button in the toolbar to start your game:



Your Unity Code Up Close



```
using UnityEngine;
```

You learned about namespaces in Chapter 3. When Unity created the file with the C# script, it added using lines so it can use code in the UnityEngine namespace and two other common namespaces.

```
public class BallBehaviour : MonoBehaviour  
{
```

```
    // Start is called before the first frame update
```

```
    void Start()  
{
```

```
}
```

A *frame* is a fundamental concept of animation. Unity draws one still frame, then draws the next one very quickly, and your eye interprets changes in these frames as movement. Unity calls the Update method for every GameObject before each frame so it can move, rotate, or make any other changes that it needs to make. A faster computer will run at a higher *frame rate*—or number of frames per second (FPS)—than a slower one.

```
    // Update is called once per frame
```

```
    void Update()  
{
```

```
        transform.Rotate(Vector3.up, 180 * Time.deltaTime);
```

```
}
```

The *transform.Rotate* method causes a GameObject to rotate. The first parameter is the axis to rotate around. In this case, your code used *Vector3.up*, which tells it to rotate around the Y axis. The second parameter is the number of degrees to rotate.

Different computers will run your game at different frame rates. If it's running at 30 FPS, we want one rotation every 60 frames. If it's running at 120 FPS, it should rotate once every 240 frames. Your game's frame rate may even change if it needs to run more or less complex code.

That's where the *Time.deltaTime* value comes in handy. Every time the Unity engine calls a GameObject's Update method—once per frame—it sets *Time.deltaTime* to the fraction of a second since the last frame. Since we want our ball to do a full rotation every two seconds, or 180 degrees per second, all we need to do is multiply it by *Time.deltaTime* to make sure that it rotates exactly as much as it needs to for that frame.

Inside your Update method, multiplying any value by *Time.deltaTime* turns it into that value per second.

Time.deltaTime is static—and like we saw in Chapter 3, you don't need an instance of the Time class to use it.

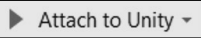

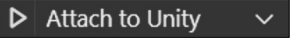
Add a breakpoint and debug your game

Let's debug your Unity game. First **stop your game** if it's still running (by pressing the Play button again). Then switch over to Visual Studio, and **add a breakpoint** on the line that you added to the Update method:

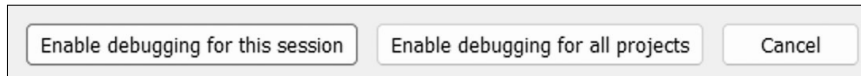
```

13 // Update is called once per frame
14 // Unity Message | 0 references
15 void Update()
16 {
17     transform.Rotate(Vector3.up, 180 * Time.deltaTime);
18 }

```

- ★ In Visual Studio, click the  button or choose Debug >> Start Debugging (F5) from the menu.
- ★ In VSCode, choose  Run and Debug (Ctrl+Shift+D) on the left, then click .

Attaching to Unity **starts the debugger**. Now switch back to the Unity editor. If this is the first time you're debugging this project, the Unity editor will pop up a dialog window with these buttons:



Press the “Enable debugging for this session” button (or if you want to keep that pop-up from appearing again, press “Enable debugging for all projects”). Visual Studio is now **attached** to Unity, which means it can debug your game.

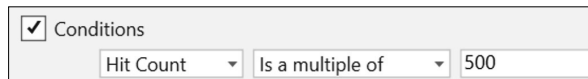
Now **press the Play button in Unity** to start your game. Since Visual Studio is attached to Unity, it **breaks immediately** on the breakpoint that you added, just like with any other breakpoint you've set.

← Congratulations, you're now debugging a game!

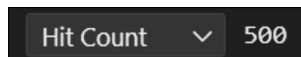
Use a hit count to skip frames

Sometimes it's useful to let your game run for a while before your breakpoint stops it. For example, you might want your game to spawn and move its enemies before your breakpoint hits. Let's tell your breakpoint to break every 500 frames. You can do that by adding a **Hit Count condition** to your breakpoint:


- ★ In Visual Studio, right-click on the breakpoint dot (●) at the left side of the line, choose **Conditions** from the pop-up menu, select **Hit Count** and **Is a multiple of** from the dropdowns, and enter **500** in the box:



- ★ In VSCode, right-click the breakpoint dot, choose **Edit breakpoint** from the dropdown, and enter **500**:



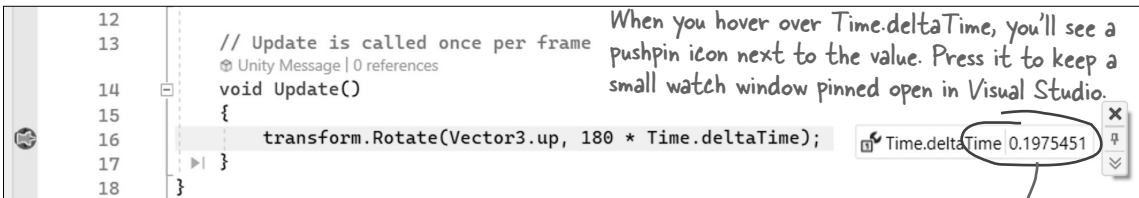
Now the breakpoint will only pause the game every 500 times the Update method is run—or every 500 frames. If your game is running at 60 FPS, then when you press Continue the game will run for a little over 8 seconds before it breaks again. **Press Continue, then switch back to Unity** and watch the ball spin until the breakpoint breaks.

 **VSCode lets you set a hit count for breakpoints just like Visual Studio does, but at the time we're writing this that feature does not work when debugging Unity projects.**

Use the debugger to understand Time.deltaTime

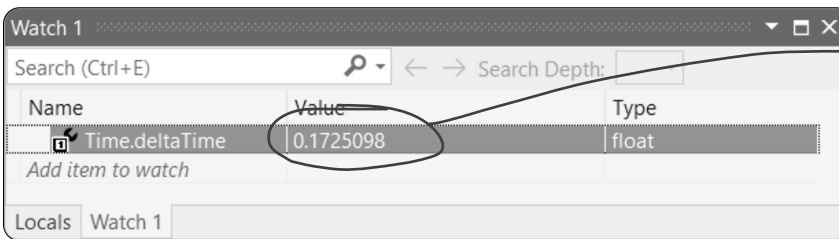
You're going to be using `Time.deltaTime` in many of the Unity Labs projects. Let's take advantage of your breakpoint and use the debugger to really understand what's going on with this value.

While your game is paused on the breakpoint in Visual Studio, **hover over `Time.deltaTime`** to see the fraction of a second that elapsed since the previous frame (you'll need to put your mouse cursor over `deltaTime`). Then **add a watch for `Time.deltaTime`** by selecting `Time.deltaTime` and choosing Add Watch from the right-mouse menu.



Every time the breakpoint pauses the game, your `Time.deltaTime` watch will show you the fraction of a second since the previous frame. Can you use this number to figure out the FPS we were getting when we took this screenshot?

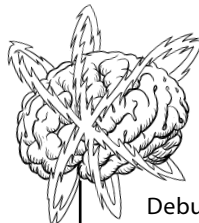
Continue debugging (F5), just like with the other apps you've debugged), to resume your game. The ball will start rotating again, and after another 500 frames the breakpoint will trigger again. You can keep running the game for 500 frames at a time. Keep your eye on the `Time.deltaTime` value each time it breaks, either in the pinned value or in the watch window.



Stop debugging (Shift + F5) to stop your program. Then **start debugging again**. Since your game is still running, the breakpoint will continue to work when you reattach Visual Studio to Unity. Once you're done debugging, **toggle your breakpoint again** so the IDE will still keep track of it but not break when it's hit. **Stop debugging** one more time to detach from Unity.

Go back to Unity and **stop your game**—and **save it**, because the Play button doesn't automatically save the game.

The Play button in Unity starts and stops your game. Visual Studio will stay attached to Unity even when the game is stopped.



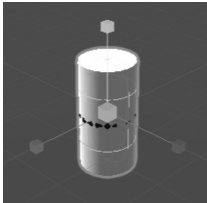
Brain Power

Debug your game again and hover over "`Vector3.up`" to inspect its value—you'll have to put your mouse cursor over "`up`." It has a value of (0.0, 1.0, 0.0). What do you think that means?

Add a cylinder to show where the Y axis is

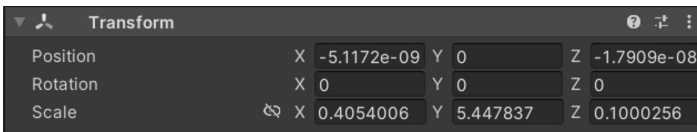
Your sphere is rotating around the **Y** axis at the very center of the scene. Let's add a very tall and very skinny cylinder to make it visible. **Create a new cylinder** by choosing 3D Object >> Cylinder from the GameObject menu. Make sure it's selected in the Hierarchy window, then look at the Inspector window and check that Unity created it at position (0, 0, 0)—if not, use the context menu (☰) to reset it.

Let's make the cylinder tall and skinny. Choose the Scale tool from the toolbar: either click on it (☐) or press the R key. You should see the Scale Gizmo appear on your cylinder:



The *Scale Gizmo* looks a lot like the Move Gizmo, except that it has cubes instead of cones at the end of each axis. Your new cylinder is sitting on top of the sphere—you might see just a little of the sphere showing through the middle of the cylinder. When you make the cylinder narrower by changing its scale along the X and Z axes, the sphere will get uncovered.

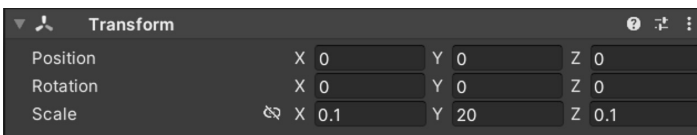
Click and drag the green cube up to elongate your cylinder along the Y axis. Then click on the red cube and drag it toward the cylinder to make it very narrow along the X axis, and do the same with the blue cube to make it very narrow along the Z axis. Watch the Transform panel in the Inspector as you change the cylinder's scale—the Y scale will get larger, and the X and Z values will get much smaller.



You might notice the Position values change when you make the X and Z Scale values very small.

Click on the X label in the Scale row in the Transform panel and drag up and down. Make sure you click the actual X label to the left of the input box with the number. When you click the label it turns blue, and a blue box appears around the X value. As you drag your mouse up and down, the number in the box goes up and down, and the Scene view updates the scale as you change it. Look closely as you drag—the scale can be positive and negative. Now **reset the Transform window.**

Now **select the number inside the X box and type 0.1**—the cylinder gets very skinny. Press Tab and type **20**, then press Tab again and type **0.1**, and press Enter.



When you edit the values in the Properties window, you can see the results update in the scene immediately.

Now your sphere has a very long cylinder going through it that shows the Y axis where Y = 0.



Add fields to your class for the rotation angle and speed

In Chapter 3, you learned how C# classes can have **fields** that store values methods can use. Let's modify your code to use fields. Add these four lines just under the class declaration, **immediately after the first curly brace {**:

```
public class BallBehaviour : MonoBehaviour
{
    public float XRotation = 0;
    public float YRotation = 1;
    public float ZRotation = 0;
    public float DegreesPerSecond = 180;
```

These are just like the fields that you added to the projects in Chapters 3 and 4. They're variables that keep track of their values—each time Update is called, it reuses the same field over and over again.

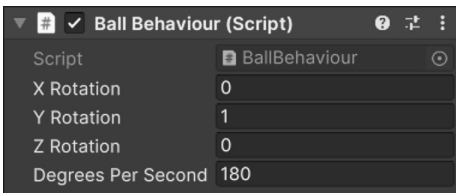
The XRotation, YRotation, and ZRotation fields each contain a value between 0 and 1, which you'll combine to create a **vector** that determines the direction that the ball will rotate:

```
new Vector3(XRotation, YRotation, ZRotation)
```

The DegreesPerSecond field contains the number of degrees to rotate per second, which you'll multiply by Time.deltaTime just like before. **Modify your Update method to use the fields.** This new code creates a Vector3 variable called **axis** and passes it to the transform.Rotate method:

```
void Update()
{
    Vector3 axis = new Vector3(XRotation, YRotation, ZRotation);
    transform.Rotate(axis, DegreesPerSecond * Time.deltaTime);
}
```

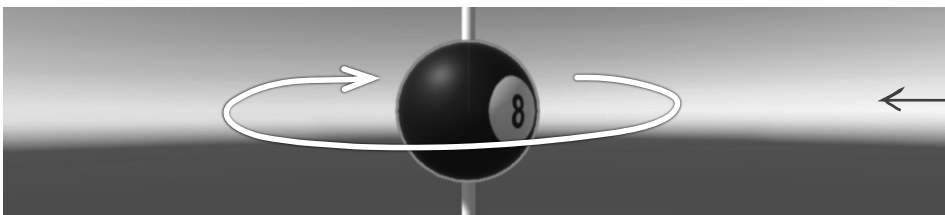
Select the Sphere in the Hierarchy window. Your fields now show up in the Script component. When the Script component renders fields, it adds spaces between the capital letters to make them easier to read.



When you add public fields to a class in your Unity script, the Script component displays input boxes that let you modify those fields. If you modify them while the game is *not* running, the updated values will get saved with your scene. You can also modify them while the game is running, but they'll revert when you stop the game.

Run your game again. **While it's running**, select the Sphere in the Hierarchy window and change the degrees per second to 360 or 90—the ball starts to spin at twice or half the speed. Stop your game—and the field will reset to 180.

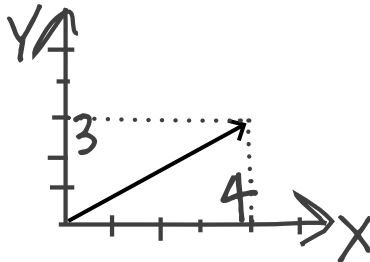
While the game is stopped, use the Unity editor to change the X Rotation field to 1 and the Y Rotation field to 0. Start your game—the ball will rotate away from you. Click the X Rotation label and drag it up and down to change the value while the game is running. As soon as the number turns negative, the ball starts rotating toward you. Make it positive again, and it starts rotating away from you.



When you use the Unity editor to set the Y Rotation field to 1 and then start your game, the ball rotates clockwise around the Y axis.

Use Debug.DrawRay to explore how 3D vectors work

A **vector** is a value with a **length** (or magnitude) and a **direction**. If you ever learned about vectors in a math class, you probably saw lots of diagrams like this one of a 2D vector:



Here's a diagram of a two-dimensional vector. You can represent it with two numbers: its value on the X axis (4) and its value on the Y axis (3), which you'd typically write as (4, 3).

That's not hard to understand...on an intellectual level. But even those of us who took a math class that covered vectors don't always have an *intuitive* grasp of how vectors work, especially in 3D. Here's another area where we can use C# and Unity as a tool for learning and exploration.

Use Unity to visualize vectors in 3D

You're going to add code to your game to help you really "get" how 3D vectors work. Start by having a closer look at the first line of your Update method:

```
Vector3 axis = new Vector3(XRotation, YRotation, ZRotation);
```

What does this line tell us about the vector?

- ★ **It has a type: Vector3.** Every variable declaration starts with a type. Instead of using string, int, or bool, you're declaring it with the type Vector3. This is a type that Unity uses for 3D vectors.
- ★ **It has a variable name: axis.**
- ★ **It uses the new keyword to create a Vector3.** It uses the XRotation, YRotation, and ZRotation fields to create a vector with those values.

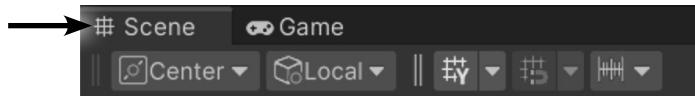
So what does that 3D vector look like? There's no need to guess—we can use one of Unity's useful debugging tools to draw the vector for us. **Add this line of code to the end of your Update method:**

```
void Update()
{
    Vector3 axis = new Vector3(XRotation, YRotation, ZRotation);
    transform.Rotate(axis, DegreesPerSecond * Time.deltaTime);
    Debug.DrawRay(Vector3.zero, axis, Color.yellow);
}
```

The Debug.DrawRay method is a special method that Unity provides to help you debug your games. It draws a **ray**—which is a vector that goes from one point to another—and takes parameters for its start point, end point, and color. There's one catch: **the ray only appears in the Scene view**. The methods in Unity's Debug class are designed so that they don't interfere with your game. They typically only affect how your game interacts with the Unity editor.

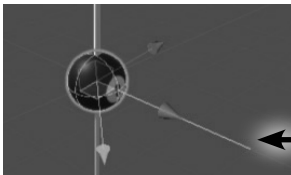
Run the game to see the ray in the Scene view

Now run your game again. You won't see anything different in the Game view because `Debug.DrawRay` is a tool for debugging that doesn't affect gameplay at all. Use the Scene tab to **switch to the Scene view**. You may also need to **reset the Wide layout** by choosing Wide from the Layout dropdown.



Now you're back in the familiar Scene view. Do these things to get a real sense of how 3D vectors work:

- ★ Use the Inspector to **modify the BallBehaviour script's fields**. Set the X Rotation to 0, Y Rotation to 0, and **Z Rotation to 3**. You should now see a yellow ray coming directly out of the Z axis and the ball rotating around it (remember, the ray only shows up in the Scene view).



The vector $(0, 0, 3)$ extends 3 units along the Z axis. Look closely at the grid in the Unity editor—the vector is exactly 3 units long. Try clicking and dragging the Z Rotation label in the Script component in the Inspector. The ray will get larger or smaller as you drag. When the Z value in the vector is negative, the ball rotates in the other direction.

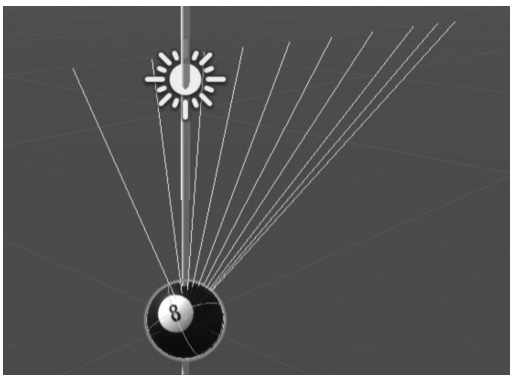
- ★ Set the Z Rotation back to 3. Experiment with dragging the X Rotation and Y Rotation values to see what they do to the ray. Make sure to reset the Transform component each time you change them.
- ★ Use the Hand tool and the Scene Gizmo to get a better view. Click the X cone on the Scene Gizmo to set it to the view from the right. Keep clicking the cones on the Scene Gizmo until you see the view from the front. It's easy to get lost—you can **reset the Wide layout to get back to a familiar view**.

Add a duration to the ray so it leaves a trail

You can add a fourth argument to your `Debug.DrawRay` method call that specifies the number of seconds the ray should stay on the screen. Add `.5f` to make each ray stay on screen for half a second:

```
Debug.DrawRay(Vector3.zero, axis, Color.yellow, .5f);
```

Now run the game again and switch to the Scene view. Now when you drag the numbers up and down, you'll see a trail of rays left behind. This looks really interesting, but more importantly, it's a great tool to visualize 3D vectors.

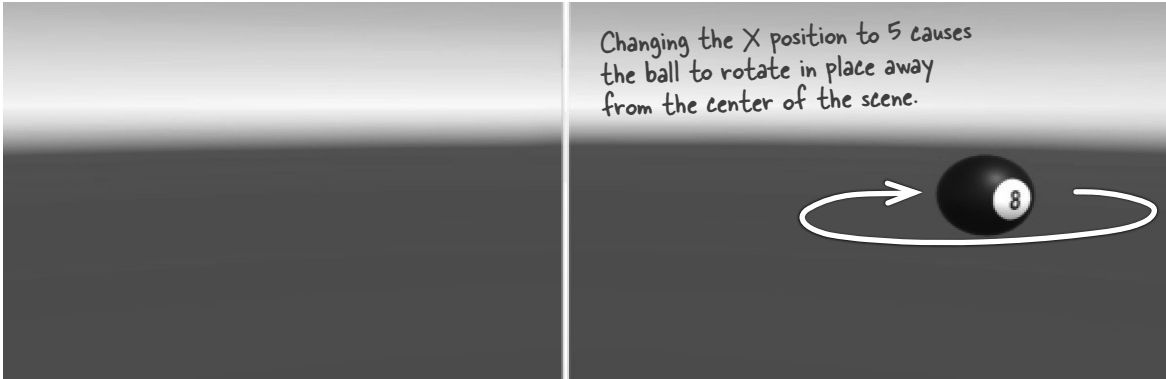


Making your ray leave a trail is a good way to help you develop an intuitive sense of how 3D vectors work.

You can use the Inspector window to modify the fields in a Script component while the game is running. The *field values will reset* when you stop the game. It will remember the values if you set them *while the game is stopped*.

Rotate your ball around a point in the scene

Your code calls the `transform.Rotate` method to rotate your ball around its center, which changes its X, Y, and Z rotation values. **Select Sphere in the Hierarchy window and change its X position to 5** in the Transform component. Then **use the context menu (☰) in the BallBehaviour Script component** to reset its fields. Run the game again—now the ball will be at position (5, 0, 0) and rotating around its own Y axis.



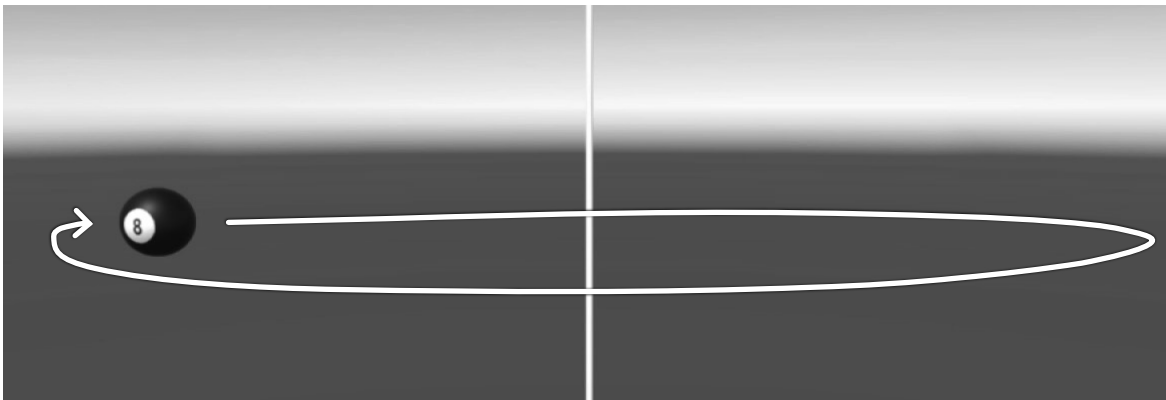
Let's modify the Update method to use a different kind of rotation. Now we'll make the ball rotate around the center point of the scene, coordinate (0, 0, 0), using the **`transform.RotateAround` method**, which rotates a `GameObject` around a point in the scene. (This is *different* from the `transform.Rotate` method you used earlier, which rotates a `GameObject` around its center.) Its first parameter is the point to rotate around. We'll use **`Vector3.zero`** for that parameter, which is a shortcut for writing **`new Vector3(0, 0, 0)`**. ↩

Here's the new Update method:

```
void Update()
{
    Vector3 axis = new Vector3(XRotation, YRotation, ZRotation);
    transform.RotateAround(Vector3.zero, axis, DegreesPerSecond * Time.deltaTime);
    Debug.DrawRay(Vector3.zero, axis, Color.yellow, .5f);
}
```

This new Update method rotates the ball around the point (0, 0, 0) in the scene.

Now run your code. This time it rotates the ball in a big circle around the center point:

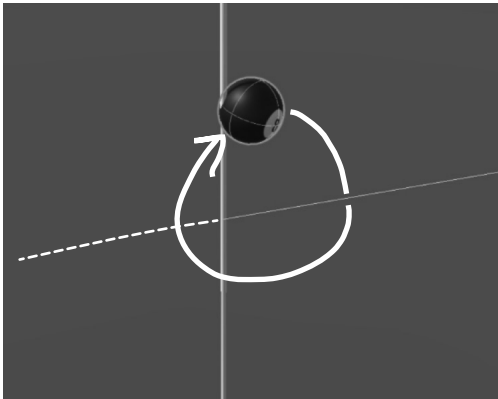


Use Unity to take a closer look at rotation and vectors

You're going to be working with 3D objects and scenes in the rest of the Unity Labs throughout the book. Even those of us who spend a lot of time playing 3D video games don't have a perfect feel for how vectors and 3D objects work, and how to move and rotate in a 3D space. Luckily, Unity is a great tool to **explore how 3D objects work**. Let's start experimenting right now.

While your code is running, try changing parameters to experiment with the rotation:

- ★ **Switch back to the Scene view** so you can see the yellow ray that `Debug.DrawRay` renders in your `BallBehaviour.Update` method.
- ★ Use the Hierarchy window to **select the Sphere**. You should see its components in the Inspector window.
- ★ Change the **X Rotation, Y Rotation, and Z Rotation values** in the Script component to **10** so you see the vector rendered as a long ray. Use the Hand tool (Q) to rotate the Scene view until you can clearly see the ray.
- ★ Use the Transform component's context menu (☰) to **reset the Transform component**. Since the center of the sphere is now at the zero point in the scene, (0, 0, 0), it will rotate around its own center.
- ★ Then **change the X position in** the Transform component to **2**. The ball should now be rotating around the vector. You'll see the ball cast a shadow on the Y axis cylinder as it flies by.



While the game is running, set the X, Y, and Z Rotation fields in the `BallBehaviour` Script component to 10, reset the sphere's Transform component, and change its X position to 2—as soon as you do, it starts rotating around the ray.

Try **repeating the last three steps** for different values of X, Y, and Z rotation, resetting the Transform component each time so you start from a fixed point. Then try clicking the rotation field labels and dragging them up and down—see if you can get a feel for how the rotation works.

Unity is a great tool to explore how 3D objects work by modifying properties on your `GameObjects` in real time.

Get creative!

This is your chance to **experiment on your own with C# and Unity**. You've seen the basics of how you combine C# and Unity GameObjects. Take some time and play around with the different Unity tools and methods that you've learned about in the first two Unity Labs. Here are some ideas:

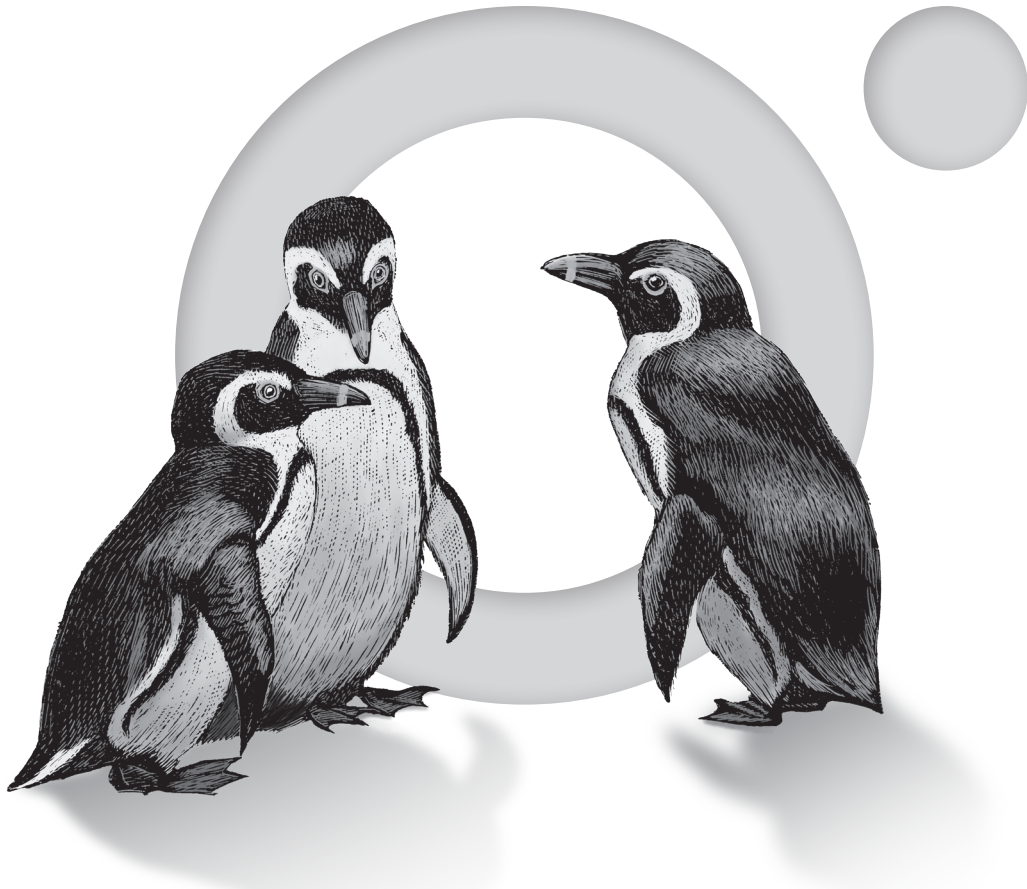
- ★ Add cubes, cylinders, or capsules to your scene. Attach new scripts to them—make sure you give each script a unique name!—and make them rotate in different ways.
- ★ Try putting your rotating GameObjects in different positions around the scene. See if you can make interesting visual patterns out of multiple rotating GameObjects.
- ★ Try adding a light to the scene. What happens when you use `transform.RotateAround` to rotate the new light around various axes?
- ★ Here's a quick coding challenge: try using `+=` to add a value to one of the fields in your `BallBehaviour` script. Make sure you multiply that value by `Time.deltaTime`. Try adding an `if` statement that resets the field to 0 if it gets too large.

Before you run the code, try to figure out what it will do. Does it act the way you expected it to act? Trying to predict how the code you added will act is a great technique for getting better at C#.

Take the time to experiment with the tools and techniques you just learned. This is a great way to take advantage of Unity and Visual Studio as tools for exploration and learning.

Bullet Points

- The **Scene Gizmo** always displays the camera's orientation.
- You can **attach a C# script** to any GameObject. The script's `Update` method will be called once per frame.
- The **`transform.Rotate` method** causes a GameObject to rotate a number of degrees around an axis.
- Inside your `Update` method, multiplying any value by **`Time.deltaTime`** turns it into that value per second.
- You can **attach** the Visual Studio debugger to Unity to debug your game while it's running. It will stay attached to Unity even when your game is not running.
- Adding a **Hit Count condition** to a breakpoint makes it break after the statement has executed a certain number of times.
- A **field** is a variable that lives inside of a class outside of its methods, and it retains its value between method calls.
- Adding public fields to the class in your Unity script makes the Script component show **input boxes that let you modify those fields**. It adds spaces between capital letters in the field names to make them easier to read.
- You can create 3D vectors using **new Vector3**. (You learned about the new keyword in Chapter 3.)
- The **`Debug.DrawRay` method** draws a vector in the Scene view (but not the Game view). You can use vectors as a debugging tool, but also as a learning tool.
- The **`transform.RotateAround` method** rotates a GameObject around a point in the scene.



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