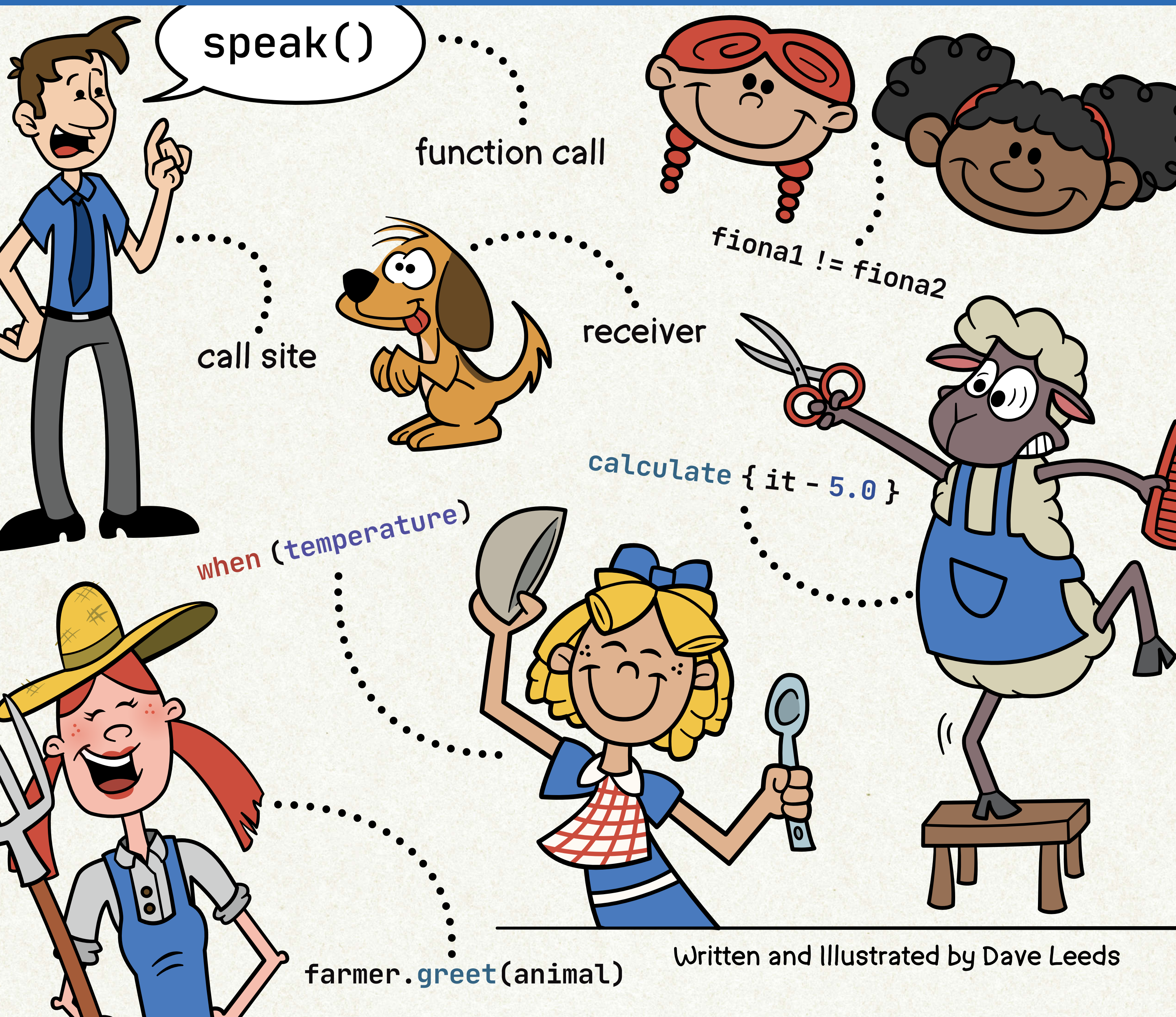
# Kotlin: An Illustrated Guide

The fun way to learn Kotlin programming, one concept at a time!




Written and Illustrated by Dave Leeds

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*Dave Leeds*

For more about Kotlin from Dave Leeds, visit https://typealias.com.

**Kotlin: An Illustrated Guide**



Version 1.0.0

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# Preface

## Who Is This Book For?

If you're interested in learning Kotlin development, this book is for you. Everyone has a unique experience—some readers are new to software development entirely, some are new to Kotlin development, and some are existing Kotlin developers who want a deeper understanding of certain language concepts. My approach in this book is to explain Kotlin programming concepts with simple, tangible, and illustrated examples, so that regardless of your experience level, things will make sense.

I do my best to define terms clearly before using them, so that as you read the book, you'll build upon a solid foundation of existing knowledge.

Even if you're familiar with some of these concepts, my goal is to present them in such a fun and vivid way that you'll enjoy revisiting them—bringing clarity to any foggy corners you may have wondered about.

## How to Read This Book

This book is written to take you on an adventure, starting with very few expectations of what you already know. I've presented the concepts and terms in a particular, cumulative order, so that you shouldn't need to interrupt your reading with web searches to figure out what different terms mean. I recommend reading the book from front to back, starting with Chapter 1 and progressing through Chapter 20.

This book also includes a few optional appendices at the end. If you're already a developer in the JVM world, you probably already know how to set up your tools, create a project, and add a dependency using Gradle or Maven. If not, these appendices will get you started.

## Source Code for This Book

The code listings in this book are brief and easy to follow, but sometimes it helps to see the surrounding context from previous examples to ensure they run properly. You can find the code listings for this book with their full context online at https://github.com/typealias-studios/kotlin-illustrated-guide.

# Acknowledgments

There are so many wonderful people who have motivated and encouraged me while I wrote this book, and I'm deeply grateful for each one of them.

## My Family

First, I'm very thankful to my wife, Elizabeth! She's been a massive support and encouragement to me at every step along the way. She's always cheering me on!

Thanks to everyone else in my family who has believed in me and encouraged me. (I also appreciate Ninja, our little Miniature Schnauzer, who sat next to me while I wrote most of the book!)

## My Mentor

A huge thank you to Beverly Jamison, who was my mentor for the first decade of my software development career. Another decade has passed since working together, but I learned so much from her, and I wouldn't be the developer—nor the person—I am today without her guidance and leadership!

## My Friends

Thanks to these friends who have been especially encouraging as I've been writing about Kotlin: Beebe, Butler, Ensor, Fleckenstein, Jared, Majtan, McSorley, Pinzur, Rakidzich, and everyone else.

## The Reviewers

Thanks so much to everyone who reviewed this book and provided feedback. James Lorenzen has been a constant reviewer for me, providing tons of amazing feedback for this book and other projects of mine throughout the past decade or so.

Others who reviewed a significant portion of this book include David Blanc, Louis CAD, Matt McKenna, Björn Michael, Mohit Sarveiya, and Doug Smith.

## JetBrains

Thanks to the Kotlin team at JetBrains for creating a language that I love using, and to the Kotlin developer advocates at JetBrains, who have encouraged me and cheered me on along the way.

## The Community

I'm very grateful to both Kotlin Weekly and Android Weekly for all the times that they've included my articles, chapters, videos, and livestreams in their weekly newsletters.

Thanks also to the entire Kotlin community for your kind words of encouragement over the years. You have no idea how much that has meant to me!

And finally, thanks to *you* for purchasing this book and supporting my work!

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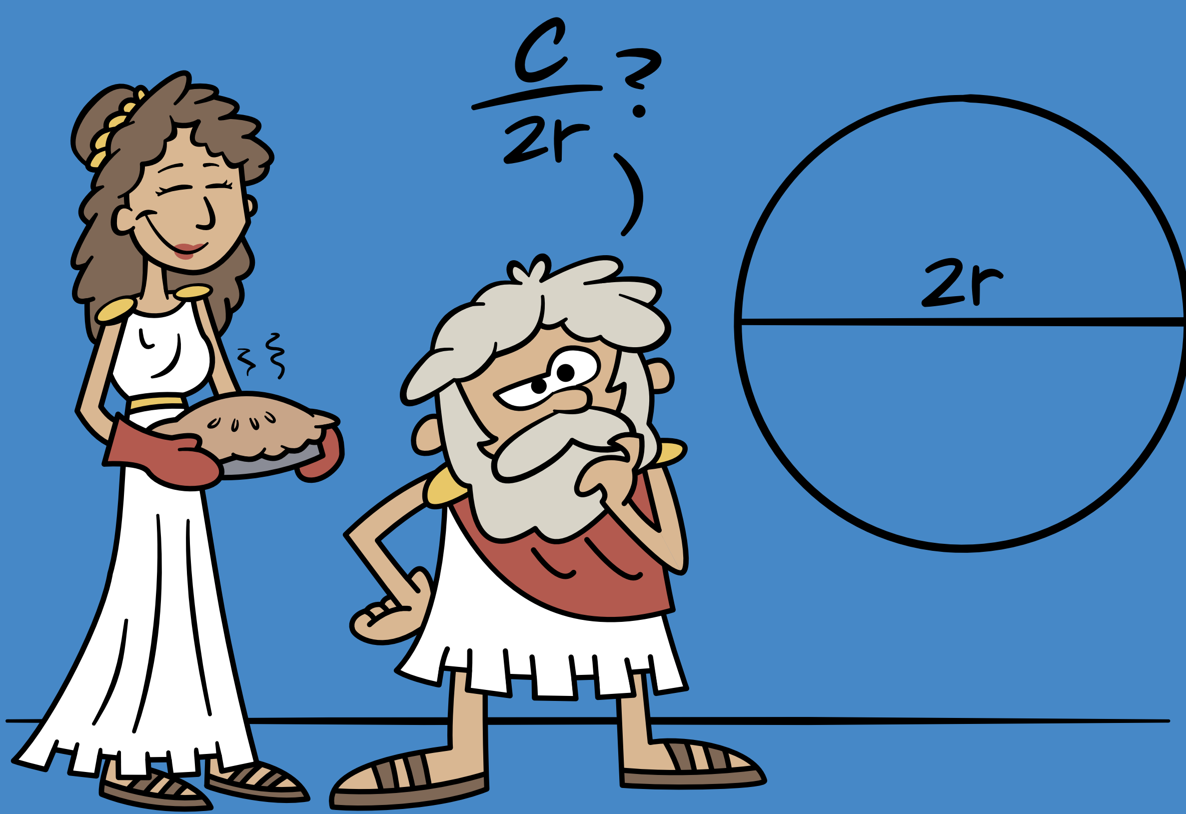
Chapter 1

# Variables, Expressions, and Types



# So you want to be a Kotlin developer?

*You've come to the right place!*

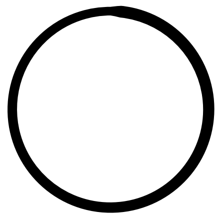
This book will take you through the fundamentals of Kotlin, gently introducing you to the most important concepts of the language in order to help you become a proficient Kotlin developer. Even if you're a seasoned pro, it's important to know the fundamentals in order to establish a solid foundation of understanding so that you can be as effective as possible.

Your adventure starts here in Chapter 1, where we'll cover the basics of variables, expressions, and types.

Let's get to it!

# Introduction to Variables

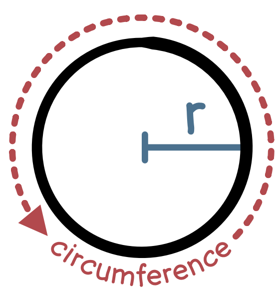
This is a circle.



In ancient Greece, Archimedes discovered how to measure the *length around a circle*, known as its *circumference*. You probably remember the equation from junior high geometry class.

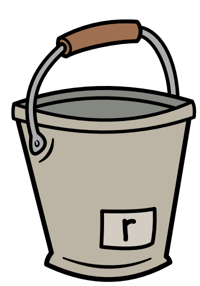
$$\text{Circumference} = 2\pi r$$

> The circumference of a circle is equal to 2 times π times the radius of the circle.




In the equation above, the letter **r** isn't a number itself. It's a letter that *represents the radius*—the distance between the center of the circle and the edge of the circle.

We call **r** a **variable**, because the radius can *vary*, depending on the size of the circle. In other words, the variable **r** isn't a number; it's kind of like a bucket that *holds* a number—any number.

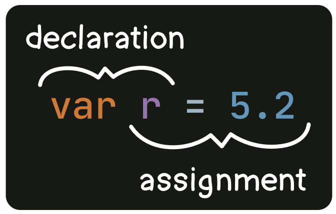


Variables aren't just for algebra and geometry. They're also used all the time in programming, where they serve the same purpose: holding numbers—and other things! In Kotlin, you can create a variable and put a number into it like this.

```
var r = 5.2
```

*Listing 1.1 - Creating a variable in Kotlin.*

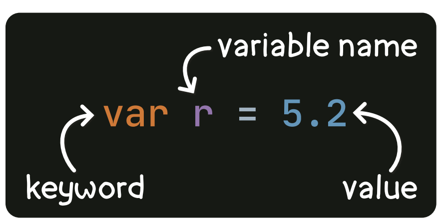
This code is actually doing *two* things on one line.




1. **Declaration** - When we write `var r`, we're declaring a new variable named `r`. Declaring a variable is kind of like creating a bucket.

2. **Assignment** - When we write `r = 5.2`, we're assigning the value of 5.2 to the variable `r`. In other words, we're putting the number 5.2 into the bucket.


Let's break down the three main parts of this line of code.




In this code:

- `var` is a **keyword** that tells Kotlin to create a new variable.
- `r` is the *name* of the variable. You might also hear this referred to as the variable's **identifier**.
- The number `5.2` is the **value** that is being assigned.

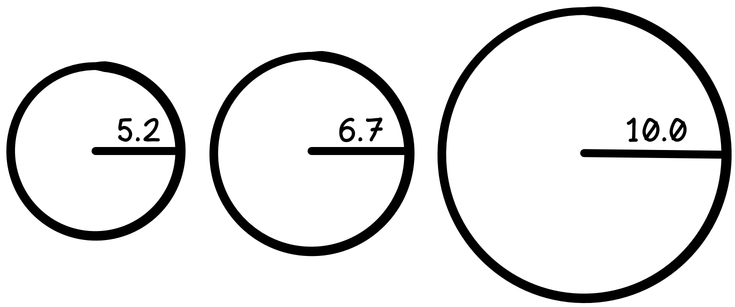
**var** is just one of many *keywords* in Kotlin that we'll see throughout this book. The important thing to remember about keywords is that they can't be used as the name of your own things. For example, you can't use **var** as the name of a variable.

```
var var = 5.2
```

*Listing 1.2 - **Error:** "Expecting property name or receiver type" (does not compile).*

## Reassigning Variables

As we noted above, in the equation 2πr, the variable **r** can represent *different* numbers in *different* situations.




In Kotlin, if we decide that we want **r** to represent a different number, we can just reassign it, as shown in the second line here.

```
var r = 5.2
r = 6.7
```

*Listing 1.3 - Assigning and then reassigning a value to a variable.*

When reassigning this variable, we didn't need to use the **var** keyword again, because the variable was already declared on the first line.

## Variables that Cannot Be Reassigned

Let's look at that circumference equation again.

$$\text{Circumference} = 2\pi r$$

The Greek letter π (pronounced like the word "pie") is very different from the variable r. Whereas r can hold *any* number in it, π only ever holds a single, specific number, which we'll approximate as 3.14.

In the same way, when programming in Kotlin, there are times when we want to make sure that a variable's value *never* changes.


In those cases, instead of declaring it with **`var`**, we declare it with **`val`**, like this.

```
val π = 3.14
```

*Listing 1.4 - Creating a read-only variable in Kotlin.*

Now, if we try to *reassign* **π**, we'll get an error.

```
val π = 3.14
π = 1.23
```

*Listing 1.5 - **Error:** "Val cannot be reassigned" (does not compile).*

Once we put something in this bucket, we can never replace it!

Note that in Kotlin, regardless of whether it was declared with **`var`** or **`val`**, it's still considered a *variable*, and that variable still has a *value*. So **π** is regarded as a variable, even though its value can't vary.

Declaring a variable with **`val`** is a great way to make sure that we don't accidentally change something that shouldn't change. In fact, it's a great idea to always *start* with **`val`**, and only switch to **`var`** when needed.

## Technically Speaking: Read-Only vs. Immutable

If you're already familiar with the concept of objects, it's important to note that **`val`** does not make objects immutable. In other words, it prevents us from putting something new in that bucket, but what's in that bucket could still change itself in some way. That's why Kotlin programmers tend to call variables declared with **`val`** "read-only" instead of "immutable".

## Naming Variables

It's been fun using the letter *π* in our code, but unless you live in Greece, you probably don't have it on your keyboard. From here on out, we'll make life easier for everyone by naming it **`pi`** instead. Also, instead of **`r`**, we'll name it **`radius`**, so that any other developers who come along later will know exactly what that variable represents—we don't want others to have to guess what the letter **`r`** stands for!

Sometimes you need more than one word for a variable's identifier. In Kotlin, it's customary to start the first word in lowercase, and then capitalize the remaining words, like this.

```
var radiusOfTheCircle = 5.2
```

*Listing 1.6 - Variable naming convention in Kotlin: camel case.*

### Best Practice: Coding Conventions

It's a good idea to write your code in a way that's similar to other developers, so that when everyone looks at it, they don't have to think too hard about it.

The official Kotlin documentation provides a set of coding conventions, and it's recommended that you follow those. In case you use IntelliJ or Android Studio, that document also tells you how you can configure a formatter that will help you more easily conform to some of those conventions.

Now that we've got down the basics of declaring and assigning variables, we can start assigning more than just *simple numbers*—we can start assigning more complex calculations, like the circumference equation! Let's dive into *expressions*!

## Expressions and Statements

Let's look at that equation one more time.

$$\text{Circumference} = 2\pi r$$

We've already created a variable for pi and a variable for the radius, so now we just need Kotlin to do some math for us, so that we can get the circumference of *any* circle, regardless of how big that circle is.

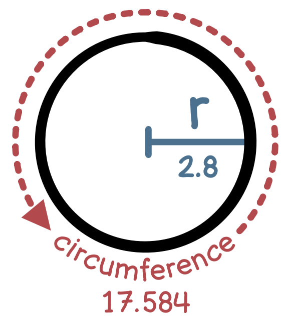
All we have to do is multiply together 2, pi, and the radius. In Kotlin, as in most programming languages, multiplication isn't represented with an x; it's represented with an asterisk `*` so our code can look like this.

```
var radius = 2.8
val pi = 3.14

val circumference = 2 * pi * radius
```

*Listing 1.7 - Assigning a complex expression to a variable.*

So far we've only assigned simple values—such as 5.2 and 3.14. This is the first time we're assigning something more complex: `2 * pi * radius`.

When Kotlin sees this, it simply calculates the result for you—it multiplies 2 times pi times radius, and then, of course, it takes the resulting value and assigns it to the variable named circumference. In this case (with a radius of 5.2), circumference will equal 17.584.




Since `2 * pi * radius` can be calculated into a value like this, we say that it can be **evaluated**. Code that can be *evaluated* is called an **expression**. Here are a few examples of expressions:

- `2 + 3`
- `2 * pi * r`
- `pi * r * r`

Variables by themselves are also expressions—they evaluate to whatever value they hold:

- `radius`
- `pi`

When we type out a number by hand (as opposed to typing a variable name), it's called a number **literal**. Literals themselves are also expressions—they evaluate to themselves! Here are a few examples:

- `2`
- `5.2`
- `3.14`

All of those examples will evaluate to some value. On the other hand, when we have a chunk of code that does *not* evaluate to a value, it's called a **statement**.

Here's an easy way to figure out if you've got an expression or a statement:

> If you can assign a chunk of code to a variable, it's an expression. Otherwise, it's a statement.

Let's apply this rule to the first expression from each of the three lists above (2 + 3, radius, and 2). In the next code listing, the highlighted parts are the expressions.

```
val a = 2 + 3
val b = radius
val c = 2
```

*Listing 1.8 - You can tell each of these is an expression because each can be assigned to a variable.*

Since each of those can be assigned to a variable, they're all expressions.

The only *statement* we've seen so far is the *assignment statement*, such as val **`pi = 3.14`**. Following the guideline above, we can try to assign this statement to a variable, but it won't work.

```
val a = val pi = 3.14
```

*Listing 1.9 - **Error:** "Expecting an expression" (does not compile).*

When we try to do this, Kotlin gives us a helpful error message, *"Expecting an expression"*. If you ever see this error message, it just means you tried to use a statement where Kotlin wanted an expression.

The distinction between *statements* and *expressions* is important as you're learning Kotlin, and we'll use those terms often throughout this book.

So far, whether we've used *literals* or *complex expressions*, we've still only ever assigned *numbers* to variables. But there are lots of other things that variables can hold! Let's explore some of these things next.

# Types: Different Kinds of Values

In Kotlin, different variables can hold different *kinds* of values. The *kind* of value that a variable holds is known as its **type**.

Let's take another look at the variables **`radius`** and **`pi`**.

```
var radius = 5.2
val pi = 3.14
```

*Listing 1.10 - Our **`radius`** and **`pi`** variables from Listing 1.7.*

In this case, both **`radius`** and **`pi`** represent *numbers that have a decimal point*, which is a type that Kotlin calls a **`Double`**. It's also possible to tell Kotlin the type of the variable explicitly, like this.

```
var radius: Double = 5.2
val pi: Double = 3.14
```

*Listing 1.11 - Explicitly specifying the type of these two variables.*

When we do this, we are *explicitly specifying* the type.

Very often, we don't have to specify the type of a variable explicitly. In that case, Kotlin will do its best to **infer** the type based on whatever it is that we're assigning to the variable. That process is called **type inference**.

So, when we write this…

```
var radius = 5.2
```

*Listing 1.12 - Allowing Kotlin to apply type inference. The radius variable still has a type of* `Double`*.*

…then Kotlin knows that `5.2` is a `Double`, so it *automatically* uses `Double` as the type of `radius`.

## Quick Tip: What Type Did Kotlin Infer?

It's usually nice to let Kotlin do type inference for you, but sometimes it'd still be nice to see what type it chose.

To see the type that Kotlin inferred, IntelliJ and Android Studio have a feature called Quick Documentation. Just put the text caret on the variable name, and hit the keyboard shortcut. By default, that shortcut is F1 on Mac, and Ctrl+Q on Windows and Linux.

In addition to `Double`, there are some other basic types that are good to know about! Let's take a look at some of those now.

## Integers and Longs

So far we've only used numbers that have a decimal point in them, such as 5.2 and 3.14. But you might also use a number that does *not* have a decimal point, like 5 or 3. These kinds of numbers are called *integers*, and in Kotlin the type for an integer is just called `Int` for short. Here's an example that creates an integer variable.

```
val numberOfDogs: Int = 3
```

*Listing 1.13 - Declaring and assigning an integer variable. Here we explicitly specify the* `Int` *type, but that's not required.*

An `Int` variable can hold a number between about negative two billion and positive two billion. For those cases where you need an integer that exceeds these limits, you can use a `Long` type, which supports much larger values.

## Booleans

Sometimes we want a variable to hold a value that is only ever *one of two values*—either on or off, yes or no, true or false, and so on.

In those cases, a `Boolean` variable can work well. There are only two Boolean values—`true` and `false`—and both of those are keywords in Kotlin.

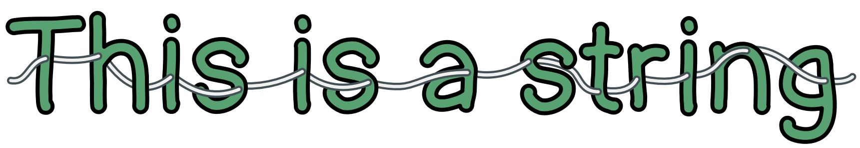
```
val puffinsCanFly: Boolean = true
val penguinsCanFly: Boolean = false
```

*Listing 1.14 - Declaring and assigning Boolean variables. Again, we explicitly specify the* `Boolean` *type, but that's not required.*

The `Boolean` type gets its name from George Boole, a British mathematician from the 1800s who came up with a branch of algebra that uses *true* and *false* instead of numbers.

## Strings

We can also assign *text* values to a variable. The fancy programmer word for text is "string" because it's a bunch of characters—such as letters, numbers, and symbols—all "strung" together.




In Kotlin, the type for this is called `String`, and we can create a `String` variable with double quotes, like this.

```
val text: String = "This is a string"
```

*Listing 1.15 - Declaring and assigning a simple* `String` *variable, explicitly specifying the type.*

# Other Types

These are just some common types of variables. In Chapter 4, we'll find out how we can create our *own* types—classes—which build upon these basic types that we just looked at.

## Types and Reassignment

In Kotlin, the type of each variable is established when we *write* the code, and its type will *never* change (unless we rewrite the code). This is why we call it **static typing**. Once a variable has been declared with a particular type, no other type of value can go into it. For example, if we create a variable of type `Int`, we can't later assign a `String` value to it.

```
var numberOfDogs: Int = 5
numberOfDogs = "five"
```

*Listing 1.16 - **Error:** "Type mismatch. Required: Int. Found: String." (does not compile).*

In future chapters, we'll see how some types can have *subtypes*. But we're getting ahead of ourselves! For now, let's wrap up this chapter.

# Summary

Good job getting through the first chapter! Here's what we covered:

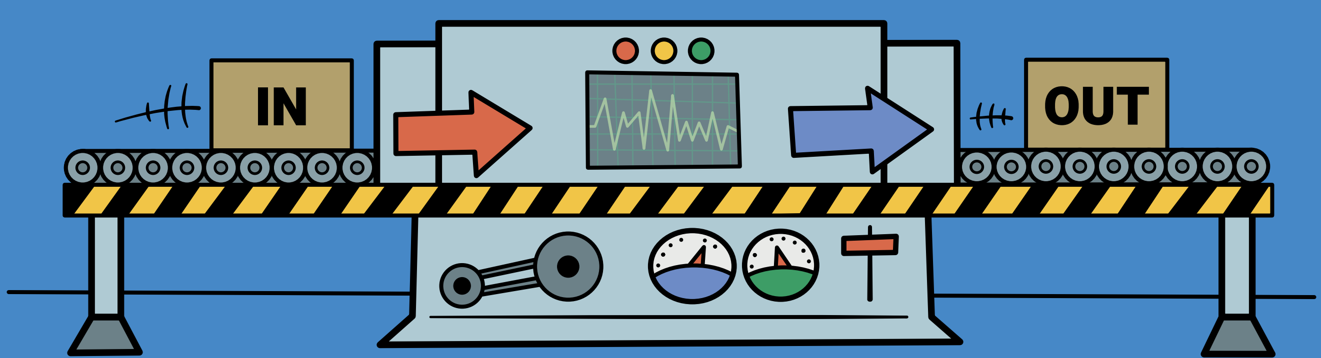
- How to use `var` for variables that can be reassigned.
- How to use `val` for variables that are read-only.
- That expressions can be evaluated to a value.
- That statements do not evaluate to a value.
- How Kotlin has number types like Double and Int.
- How we can use the Boolean type for true and false values.
- How we can use the String type for text values.

Now that you've got a good grasp on variables, it's time to put them together in exciting new ways! In the next chapter, we'll explore functions, which take input, process it, and deliver a result—without repeating the same expressions throughout our code.

Kotlin: An Illustrated Guide

Chapter 2

# Functions



## Don’t duplicate those expressions!

In the last chapter, we wrote some Kotlin code to calculate the circumference of individual circles. Once we start calculating the circumference of many circles of different sizes, we can easily end up writing the same code over and over again.

In this chapter, we’re going to write *functions*, which will make it easy to calculate the circumference of *any* circle—without repeating ourselves!

# Introduction to Functions

In the last chapter, we saw that it's easy to calculate the circumference of a circle.

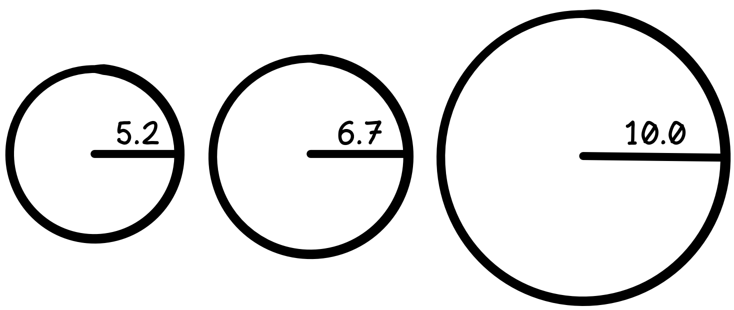
$$\text{Circumference} = 2\pi r$$

We also saw how easy it is to write Kotlin code to calculate it for us.

```
val pi = 3.14
var radius = 5.2
val circumference = 2 * pi * radius
```

*Listing 2.1 - Calculating the circumference of a circle that has a radius of 5.2.*

The code above calculates the circumference of a circle that has a radius of 5.2. But of course, not all circles have a radius of 5.2! What happens if we also want to determine the circumference of a circle that has a radius of 6.7? Or 10.0?




Well, we *could* just write out the equation multiple times.

```
val pi = 3.14

var radius = 5.2
val circumferenceOfSmallCircle = 2 * pi * radius

radius = 6.7
val circumferenceOfMediumCircle = 2 * pi * radius

radius = 10.0
val circumferenceOfLargeCircle = 2 * pi * radius
```

*Listing 2.2 - Calculating the circumference of a circle that has a radius of 5.2, and another with radius 6.7, and another with radius 10.0.*

This certainly works, but *wow*—look at how we had to type the same thing *over* and *over* again!

```
val pi = 3.14

var radius = 5.2
val circumferenceOfSmallCircle = 2 * pi * radius

radius = 6.7
val circumferenceOfMediumCircle = 2 * pi * radius

radius = 10.0
val circumferenceOfLargeCircle = 2 * pi * radius
```

same thing

When we have the same code over and over again like this, we call it **duplication**. In most cases, *duplicated* code is bad because:

1. When we type the same thing so many times, it becomes more likely that we might type it wrong in one of those cases. For example, one time, we might accidentally type `3 * pi radius.`
2. If we want to change the equation, we'd have to find all of the places where we typed it, and make sure to update each one of them.
3. It can be more difficult to read the code when our eyes see the same thing written over and over again on the screen.

Let's change our code so that we only have to write `2 * pi * radius` *one* time, and then use that to calculate the circumference of *any* circle. In other words, let's remove the duplication!

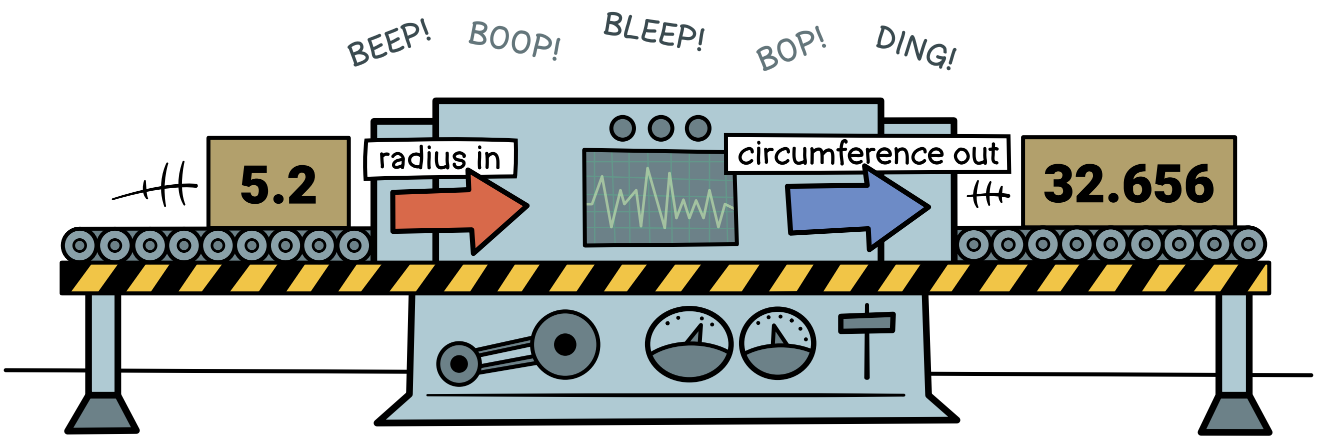
# Removing Duplication with Functions

Even though we wrote `2 * pi * radius` three times, the only thing that actually changed each time was the `radius`. In other words, `2` never changed, and `pi` never changed (it equaled `3.14` each time). But the value of `radius` was different each time: first `5.2`, then `6.7`, and then `10.0`.

Since the radius is the only thing that changes each time, it would be amazing if we could just convert any *radius* into a *circumference*. In other words, what if we could build a *machine* where we insert a radius on one side, and a circumference pops out of the other side?

- Since we're **putting in** a radius, we call that the **input**.
- And since a circumference comes **out** of the other side, we call that the **output**.

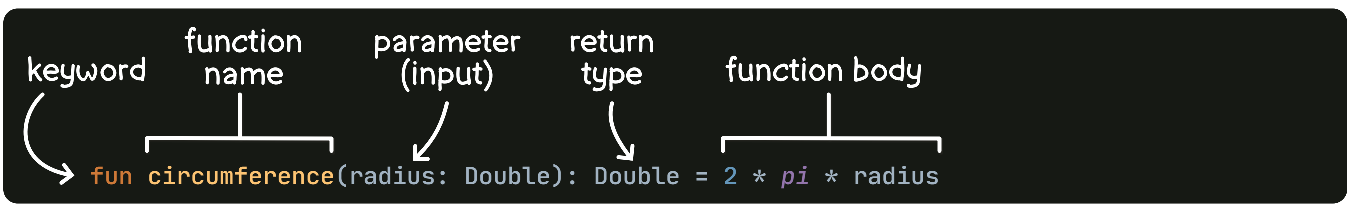
Now, we won't be creating a *real* machine, but instead, we will create a **function**, which will do exactly what we want—we'll give it a *radius* and get a *circumference* back from it!




# Function Basics

## Creating a Function

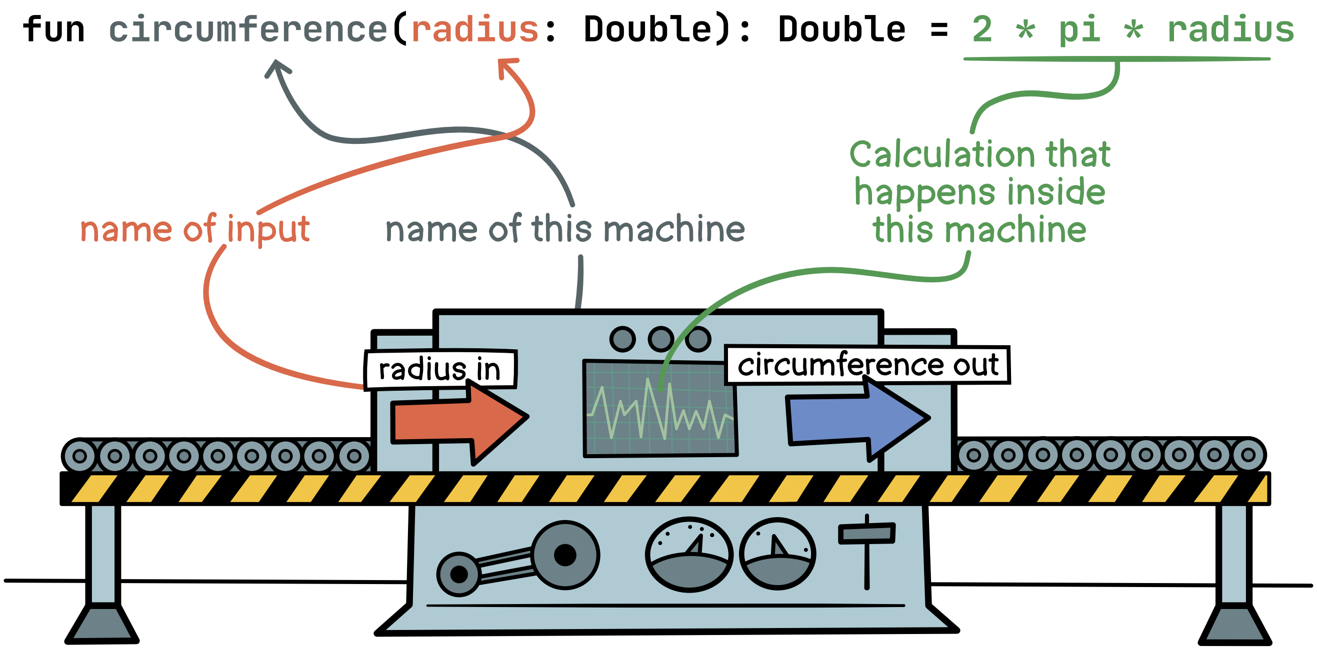
Here's how we can write a simple function in Kotlin.




This looks like a lot, but there are really just a few pieces, and they're all easy to understand.

1. First, `fun` is a keyword (just like `val` and `var` are keywords). It tells Kotlin that we are writing a **fun**ction.
2. Next, `circumference` is the **name** of our function. Much like variable names, we can name a function just about anything we want, like `circumference`, `getCircumference`, `circ`, or even just `c`.
3. Then, `(radius: Double)` says that this function has an *input* called `radius`, which has a type called `Double`. We call `radius` a **parameter** of this function.
4. Then, the `": Double"` after the closing parenthesis indicates that the output of the function will be a `Double` value. This is called the **return type** of the function.
5. And finally, `2 * pi * radius` is called the **body** of the function. Whatever this expression evaluates to will be the *output* of the function. The *value* of that output is referred to as the **result** of the function. It's the thing that comes out of the machine. Note that whatever this expression evaluates to *must* be the same type that's specified by the return type. In this example, `2 * pi * radius` must evaluate to a `Double` or we'll get an error.

In the image below, we can compare our function with the machine we imagined earlier.




As mentioned in the last chapter, when we declare a variable, we often don't have to specify its type explicitly. Instead, we can let Kotlin use its type inference.

We can also use type inference when writing *functions*. Just leave off the return type, so that it looks like this.

```
fun circumference(radius: Double) = 2 * pi * radius
```

*Listing 2.3 - Using Kotlin's type inference on a function by leaving off the return type.*

Kotlin programmers often use type inference for simple functions like this one. By the end of this chapter, we'll see some more complex functions where we will *have* to specify the return type explicitly.

And now that we've created our function, it's time to use it!

## Quick Tip: Inlay Hints

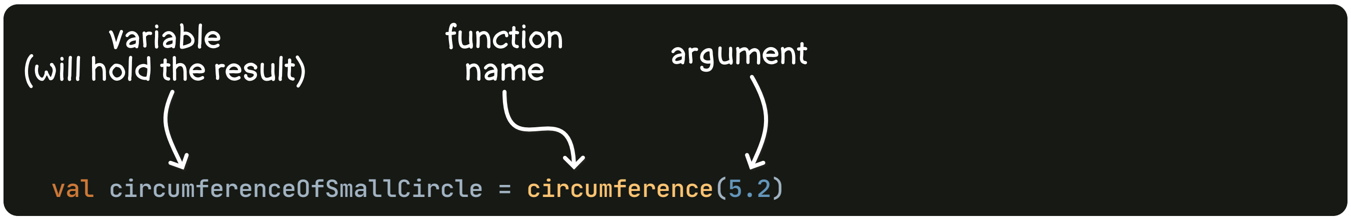
If you're using IntelliJ or Android Studio, there's a setting that will let you see what the return type is, even when you're using type inference. To turn it on, open *Settings/Preferences*, search for "Inlay Hints", and enable them for *types*.

If you don't always want to see the hints, you can create a keyboard shortcut to *Toggle Inlay Hints Globally* under the *Keymap* section of the settings. Then you can use that keyboard shortcut to turn them on or off.

## Calling a Function

When we use the function—that is, when we put something into the machine—it's referred to as **calling** or **invoking** the function. The place where it is called is known as the **calling code** or the **call site**.

Here's how we can call a function in Kotlin.




1. First, **`circumferenceOfSmallCircle`** is a variable that will hold the *result* of the function call (that is, whatever comes out of the machine).

2. Next, **`circumference`** is the *name* of the function that we're calling.

3. The value **`5.2`** is the **argument** of this function—it's the thing that we're putting into the machine. When we call a function with an argument, we sometimes say that we are **passing** the argument to the function.

### By the Way: Function Names

From this point forward in the book, function names will have parentheses after them in order to distinguish them from variable names. For example, rather than **`circumference`**, it'll be written as **`circumference()`**.

What happens when we call a function? Let's say we wrote a function and called it, like this.

```
fun circumference(radius: Double) = 2 * pi * radius

val circumferenceOfSmallCircle = circumference(5.2)
```

*Listing 2.4 - A function definition and a function call.*

When we call that function, it's kind of like we're just dropping the body of the function—**`2 * pi * radius`**—right where we see the function call—**`circumference(5.2)`**. So we can imagine that it looks like the next code listing.

```
fun circumference(radius: Double) = 2 * pi * radius

val circumferenceOfSmallCircle = 2 * pi * radius
```

*Listing 2.5 - When you call a function, it's almost like you're substituting the function call with the body of the function.*

Then, since we passed **`5.2`** as the **`radius`**, we could imagine substituting the value **`5.2`** where we had dropped in **`radius`**.

```
fun circumference(radius: Double) = 2 * pi * radius

val circumferenceOfSmallCircle = 2 * pi * 5.2
```

*Listing 2.6 - When calling a function, imagine that you're substituting the parameter name with the argument value that was passed in.*

So, when we call **`circumference(5.2)`**, it's as if we had written **`2 * pi * 5.2`** at the same spot.

Now that we've got a function that can calculate the circumference from a radius, we can call that function as many times as we need!

```
val pi = 3.14
fun circumference(radius: Double) = 2 * pi * radius

val circumferenceOfSmallCircle = circumference(5.2)
val circumferenceOfMediumCircle = circumference(6.7)
val circumferenceOfLargeCircle = circumference(10.0)
```

*Listing 2.7 - Calling the **`circumference()`** function three times in a row.*

This looks so much cleaner than our original code! Because we have a function, we don't need to write **`2 * pi * radius`** over and over! Instead, we just call the **`circumference()`** function once for each circle.

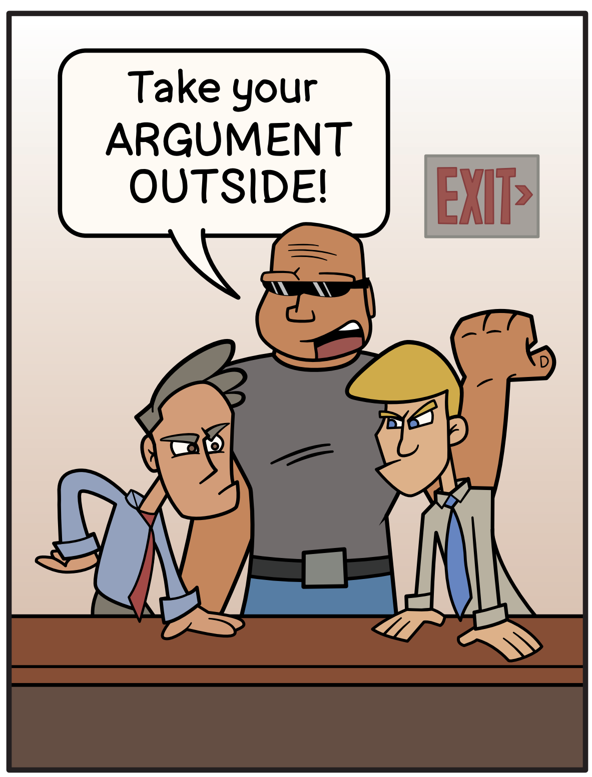
## Arguments and Parameters: What's the difference?

It's easy to confuse an argument with a parameter, so it's important to understand the distinction:

1. An **argument** is a *value* that we pass to the function. For example, when we pass **`5.2`** into the **`circumference()`** function, the argument is **`5.2`**.

2. A **parameter** is effectively a variable inside the function that will hold that value. For example, when we pass **`5.2`** to **`circumference()`**, it is assigned to the parameter named **`radius`**.

An argument is a value that usually comes from *outside* of the function, whereas a parameter is declared *inside* the function. As a mnemonic, simply associate the word "argument" with the word "outside", as shown in the cartoon.



# Functions with More Than One Parameter

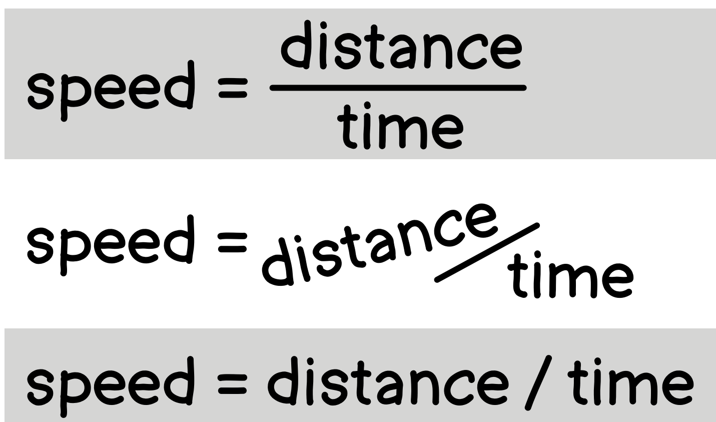
The **`circumference()`** function above has just *one* parameter, named **`radius`**, but there are times when we might need a function that has *more* than that. Let's create a function that has *two* parameters!

Even if physics class was a while ago, you probably know how to calculate *speed*. It's easy to remember, because we say it aloud all the time—"Your speed is 100 kilometers per hour".

Speed—e.g., "Kilometers per hour"—is just distance ("kilometers") divided by ("per") time ("hour").

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

In Kotlin, we use a *forward slash* to represent division. It looks kind of like a fraction that fell over to the left.




To start with, let's just write some simple code to calculate the average speed of a car that has traveled 321.8 kilometers in 4.15 hours.

```
val distance = 321.8
val time = 4.15
val speed = distance / time
```

*Listing 2.8 - Calculating speed without using a function.*

Now, let's turn that **`distance / time`** expression into a function. In order to create a function for speed, we need to know *two* things: **`distance`** *and* **`time`**. In Kotlin, when we need a function with two parameters, we can just separate those parameters with a comma.

```
fun speed(distance: Double, time: Double) = distance / time
```

*Listing 2.9 - Defining a function that has two parameters.*

When we need to call this function, the *arguments* are also separated with a comma. For example, we can call the `speed()` function with the same values as we used above, separating those values with a comma.

```
val averageSpeed = speed(321.8, 4.15)
```

*Listing 2.10 - Calling a function that has two parameters.*

The result is approximately `77.54` kilometers per hour.

Note that the arguments here are in the *same order* as the parameters.

- Since `321.8` is the *first* argument, `321.8` will be assigned to the *first* parameter, which is `distance`.
- Since `4.15` is the *second* argument, `4.15` will be assigned to the *second* parameter, which is `time`.

In other words, the *position* of the argument matters when we call a function this way, which is why we refer to arguments like these as **positional arguments**.

```
fun speed(distance: Double, time: Double) = distance / time


val averageSpeed = speed(321.8, 4.15)
```

But this isn't the *only* way to pass arguments to a function!

# Named Arguments

Rather than relying on the *position* of the arguments, we can instead use the *name* of the parameter, like this.

```
val averageSpeed = speed(distance = 321.8, time = 4.15)
```

*Listing 2.11 - Calling a function using named arguments instead of positional arguments.*

These are called **named arguments**. The neat thing about named arguments is that the order doesn't matter. So, we can call the function like this, with the arguments in a different order.

```
val averageSpeed = speed(time = 4.15, distance = 321.8)
```

*Listing 2.12 - Using named arguments to reverse the order of two arguments.*

In fact, in the code below, all five function calls will end up with the exact same result.

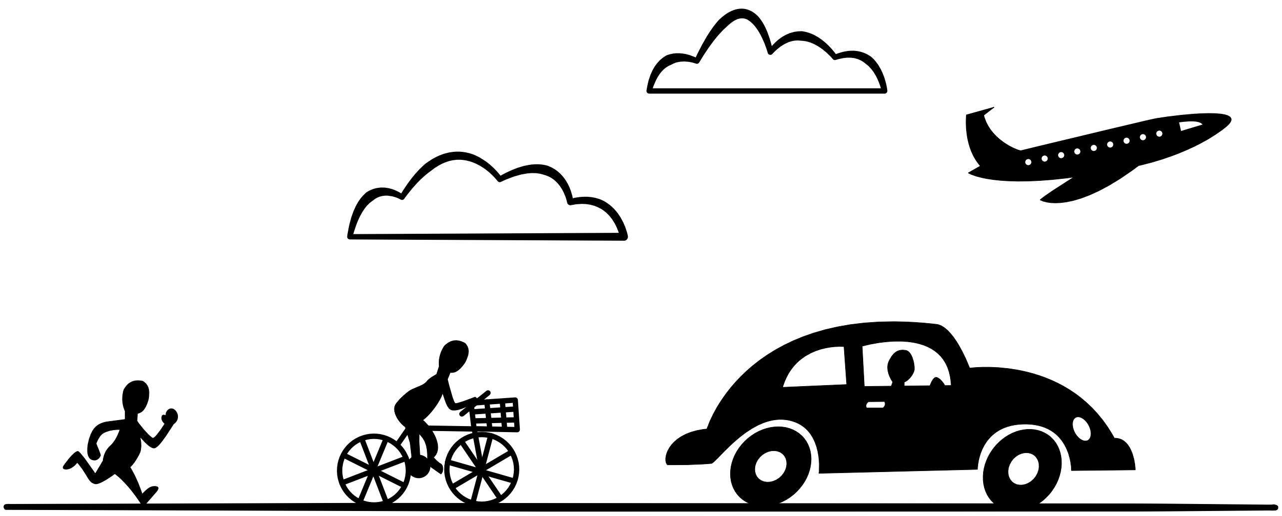
```
val averageSpeed1 = speed(321.8, 4.15)
val averageSpeed2 = speed(distance = 321.8, 4.15)
val averageSpeed3 = speed(321.8, time = 4.15)
val averageSpeed4 = speed(distance = 321.8, time = 4.15)
val averageSpeed5 = speed(time = 4.15, distance = 321.8)
```

*Listing 2.13 - Multiple ways to call a function with the same two arguments.*

# Default Arguments

In some cases, we might end up passing the same argument value to a function over and over again. For example, we might want to calculate how fast…

1. One person is walking.
2. Another person is biking.
3. A third person is driving a car.
4. A fourth person is flying a plane.



Everybody was moving for 2.0 hours, except for the plane, which got to its final destination in only 1.5 hours. Using our `speed()` function from above, we can calculate their speeds like this.

```
val walkingSpeed = speed(10.2, 2.0)
val bikingSpeed = speed(29.6, 2.0)
val drivingSpeed = speed(225.3, 2.0)
val flyingSpeed = speed(1368.747, 1.5)
```

*Listing 2.14 - Calling a function with the same argument value. The time is 2.0 for the first three function calls.*

Instead of having to pass `2.0` for the `time` parameter over and over, we could make `2.0` a **default argument** when we define the function.

Let's update our `speed()` function so that the `time` parameter defaults to `2.0`.

```
fun speed(distance: Double, time: Double = 2.0) = distance / time
```

*Listing 2.15 - A function with a default second argument.*

Now we can omit the argument for `time` whenever it should equal `2.0`.

```
val walkingSpeed = speed(10.2)
val bikingSpeed = speed(29.6)
val drivingSpeed = speed(225.3)
val flyingSpeed = speed(1368.747, 1.5)
```

*Listing 2.16 - Calling a function with a default argument.*

For walking, biking, and driving, we left off the **`time`** argument, so those defaulted to **`2.0`**. But for flying, we passed **`1.5`**. The results for Listing 2.16 are exactly the same as those for Listing 2.14.

But what happens when we want a default argument for the *first* parameter instead of the *second* parameter?

## When a Default Argument Comes First

Our walker, biker, driver, and pilot are at it again. But this time, it's a race! Whoever gets to the finish line 42.195 kilometers away gets the prize.

Everyone finished the race, except for the airplane, which got a flat tire before it could get off the ground.

```
val walkingSpeed = speed(42.195, 8.27)
val bikingSpeed = speed(42.195, 2.85)
val drivingSpeed = speed(42.195, 0.37)
val flyingSpeed = speed(0.12, 0.01)
```

*Listing 2.17 - Calling a function with the same argument value. The distance is 42.195 for the first three function calls.*

Since the distance is 42.195 for everyone except the airplane, let's update our code—we'll remove the default for **`time`**, and instead give it a default **`distance`** of **`42.195`**.

```
fun speed(distance: Double = 42.195, time: Double) =
    distance / time
```

*Listing 2.18 - A function with a default first argument.*

Now, since the walker, the biker, and the driver all travel the same distance, we should be able to omit the value for the first parameter, **`distance`**. It might be tempting to call the function as we're doing in Listing 2.19 below, but it actually causes an error: *No value passed for parameter 'time'.*

```
val walkingSpeed = speed(8.27)
val bikingSpeed = speed(2.85)
val drivingSpeed = speed(0.37)
val flyingSpeed = speed(0.12, 0.01)
```

*Listing 2.19 - **Error:** "No value passed for parameter 'time" (does not compile).*

Why did that happen?

Since we're using a *positional argument*, we actually ended up omitting *time* instead of *distance*. In other words, we *wanted* to assign `8.27` to the `time` parameter.

```
fun speed(distance: Double = 42.195, time: Double) = distance / time


val walkingSpeed = speed(8.27)
```

…but we actually assigned `8.27` to the `distance` parameter, because `8.27` is the *first* argument, and `distance` is the *first* parameter.

```
fun speed(distance: Double = 42.195, time: Double) = distance / time


val walkingSpeed = speed(8.27)
```

To tell Kotlin that we're sending the `time` instead, we simply use *named arguments*, like this.

```
val walkingSpeed = speed(time = 8.27)
val bikingSpeed = speed(time = 2.85)
val drivingSpeed = speed(time = 0.37)
val flyingSpeed = speed(0.12, 0.01)
```

*Listing 2.20 - Accepting the default argument for the first parameter of a function.*

With these changes, when we call `speed()` for walking, biking, and driving, the first parameter—`distance`—will default to `42.195`.

# Expression Bodies and Block Bodies

So far we've been writing functions that simply evaluate an expression.

- Our `circumference()` function just evaluates `2 * pi * radius`.
- Our `speed()` function just evaluates `distance / time`.

Let's look at our code for `circumference()` again.

```
val pi = 3.14

fun circumference(radius: Double) = 2 * pi * radius
```

*Listing 2.21 - Our* `circumference()` *function, which has an expression body.*

When we write a function this way, where the body is just a *single expression*, we say that the function has an **expression body**.

Kotlin also gives us a second way that we can write functions. Let's rewrite the **`circumference()`** function using this second way.

```
val pi = 3.14

fun circumference(radius: Double): Double {
    return 2 * pi * radius
}
```

*Listing 2.22 - Our* **`circumference()`** *function, rewritten to have a block body.*

When we write a function this way, we say that it has a **block body**. Writing a function with a *block body* is a little more complex than writing it with an *expression body*, so let's take a closer look at the new pieces:

First, notice the **`: Double`** after the parentheses. We were able to use type inference for expression bodies, but when we use a block body, we *must* specify the return type explicitly (with one exception, which we'll see in a moment).

Next, notice the opening and closing braces: **`{`** and **`}`**. Everything between those two braces is referred to as a **code block** (which is why we call this a function with a *block* body!)

Finally, notice the word **`return`** inside that code block. The word **`return`** is a keyword that tells Kotlin that the expression that follows it is what the function should return. As with expression body functions, the value that the function returns must match the type that we said the function returns!

```
fun circumference(radius: Double): Double {
   return 2 * pi * radius
}
```

whatever is returned here must match the type indicated here

Clearly, we have to type more code when writing functions with a block bodies than those with an expression bodies, so why would we ever want to use them?

- They let us write more than one line of code in the function.
- They let us write statements inside them, not just expressions.

For example, so far we have defined **`pi`** *outside* of our function, like in Listing 2.22. But it'd be great to define it *inside* the function instead.

```
fun circumference(radius: Double): Double {
    val pi = 3.14
    return 2 * pi * radius
}
```

*Listing 2.23 - A block body with multiple lines.*

By moving `pi` to the inside of the function like this, it will only be **accessible** from *inside* the function. In other words, if we try to use it outside of the function, we'll get an error.

```
fun circumference(radius: Double): Double {
    val pi = 3.14
    return 2 * pi * radius
}

val tau = 2 * pi
```

*Listing 2.24 - **Error:** "Unresolved reference: pi" (does not compile).*

Throughout the rest of this book, we'll see many examples of both kinds of functions—those with expression bodies and those with block bodies.

### Best Practice: Expression Bodies and Block Bodies

- When you've got a function that just evaluates a simple expression, it's conventional in Kotlin to use an expression body instead of a block body.
- Even though functions with block bodies can have as many lines of code as you want, functions are usually easier to understand when you keep them short.

## Functions without a Result

Sometimes we don't need a result from our function. For example, let's say we've got a variable named **`counter`**, which keeps track of a number that increases over time, and a function named **`increment()`**, which increases **`counter`** by one every time we call it. To increment the **`counter`** variable, we can use the statement **`counter = counter + 1`**. As we've seen, functions with *expression bodies* can only contain a single expression. We can't use a statement in an expression body, so the following code won't work.

```
var counter = 0

fun increment() = counter = counter + 1
```

*Listing 2.25 - **Error:** "Assignments are not expressions, and only expressions are allowed in this context".*

Instead of using an expression body, let's use a block body for this function instead.

```
var counter = 0

fun increment() {
    counter = counter + 1
}
```

*Listing 2.26 - A function with a block body that does not specify a return type.*

Did you notice that we didn't specify a return type on this function?

no return type here

```
fun increment() {
    counter = counter + 1
}
```

You might be surprised to learn that, even though we didn't specify a return type, and even though this function contains no expression, this function *still returns a value*.

That's right! When we omit a return type for a function that has a block body, it *automatically* returns a special Kotlin type called **`Unit`**. **`Unit`** isn't a *meaningful* result—it's not a number or a string, and you can't really do much with it. But in Kotlin, every function technically returns *something*, even if it's just **`Unit`**. This is actually useful because it ensures that every function call in Kotlin is an *expression* that can be evaluated.

# The `main()` function

We've created a variety of functions throughout this chapter, and each time, we were able to name the function whatever we wanted. However, if we name our function **`main()`**, then it'll be regarded as a *special* function that acts as the front door, or **entry point**, to the rest of our code.

For example, we can create a **`main()`** function that will call the **`circumference()`** function three times, each time with a different value.

```
val pi = 3.14

fun circumference(radius: Double): Double {
    return 2 * pi * radius
}

fun main() {
    var c = circumference(0.75)
    c = circumference(3.8)
    c = circumference(1.0)
}
```

*Listing 2.27 - A* **`main()`** *function that calculates the circumference for three* **`radius`** *values.*

If you're writing your Kotlin code in IntelliJ, you'll probably see a green play icon to the left of the **`main()`** function.

When you click on that, you can run the code inside the **`main()`** function.

```
fun main() {
    var c = circumference(0.75)
    c = circumference(3.8)
    c = circumference(1.0)
}
```

play icon

By the end of the `main()` function in Listing 2.27, the value of the `c` variable will be `6.28`. However, as things currently are, we don't have a way to actually *see* the value! To address this, let's start printing things to the screen!

# Printing to the Screen

As we've seen, we can create our *own* functions, but Kotlin also includes many functions that are ready for you to use! The functions that Kotlin provides are all bundled together as part of its **standard library**. In fact, the types that we've seen so far—`Double`, `Int`, `Boolean`, and `String`—all come from the standard library, too!

To print out a message to the screen, we'll use the `println()` function from the standard library. This function is pronounced "print line", because it prints a line of text to the screen. We can pass it any kind of object, and Kotlin will do its best to write out information about that object. But it's most common to just give it a string.

Here's a simple example demonstrating how we can use it.

```
fun main() {
    println("This message will be printed on the screen.")
}
```

*Listing 2.28 - Printing a message to the screen.*

When we run this, we'll see the string printed out on the screen.

```
This message will be printed on the screen.
```

We can also include an *expression* inside the string. When the *string* is evaluated, that *expression* will be evaluated, and its result will be inserted. For example, we can print the circumference of a circle.

```
println("The circumference is ${circumference(1.0)}")
```

*Listing 2.29 - Printing a templated string.*

This feature is called **string interpolation**, and a string that includes an expression is called a **templated string**. To add an expression to your string, include a dollar sign `$`, an opening brace `{`, the expression to evaluate—e.g., `circumference(1.0)`—, and a closing brace `}`. In the code above, `circumference(1.0)` will be evaluated to `6.28`, so the final string on the screen will look like this:

```
The circumference is 6.28
```

When the expression is simply a variable name, we can omit the braces—just use a dollar sign and the name of the variable. For example, we could print out both the radius and the circumference.

```kotlin
val radius = 1.0
println("The radius is $radius and the circumference is ${circumference(radius)}")
```

*Listing 2.30 - Using string interpolation with a simple variable and a more complex expression.*

The `println()` function is one of the most helpful functions to know when learning Kotlin, because we can use it to inspect the value of a property or the result of a function call. Whenever your code isn't doing what you think it should be doing, you can use `println()` to help figure out why—in other words, it's a simple way to **debug** your code. For example, we can use it in our `main()` function to see what the circumference is at each step along the way.

```kotlin
fun main() {
    var c = circumference(0.75)
    println(c)
    c = circumference(3.8)
    println(c)
    c = circumference(1.0)
    println(c)
}
```

*Listing 2.31 - Printing the value of `c` after each call to `circumference()`.*

## By the Way: Precision

When printing out the circumference of certain numbers, you might be surprised to see a value that's off by a small amount. For example, you might expect `circumference(5.2)` to evaluate to `32.656`, but it might actually print as `32.656000000000006`.

This is known as a **precision issue**, and it exists because of the way that `Float` and `Double` types are represented internally. When working on a project that needs to have precise fractions—such as financial software that deals with money—it's important to use types that will be more precise, like integers or `BigDecimal`.

Note that, although you typically need to use a `main()` function to run your code, the code listings throughout this book will usually omit the `main()` function for brevity and focus. Instead, they'll simply include the *contents* of the `main()` function directly. For example, instead of this…

```kotlin
fun main() {
    var c = circumference(0.75)
    c = circumference(3.8)
    c = circumference(1.0)
}
```

*Listing 2.32 - A full `main()` function.*

… the code listings will usually only look like this.

```
var c = circumference(0.75)
c = circumference(3.8)
c = circumference(1.0)
```

*Listing 2.33 - Only the contents of the* `main()` *function from the previous listing.*

If you're ever in doubt, simply consult the online source code for this book. You can find the source code at https://github.com/typealias-studios/kotlin-illustrated-guide.

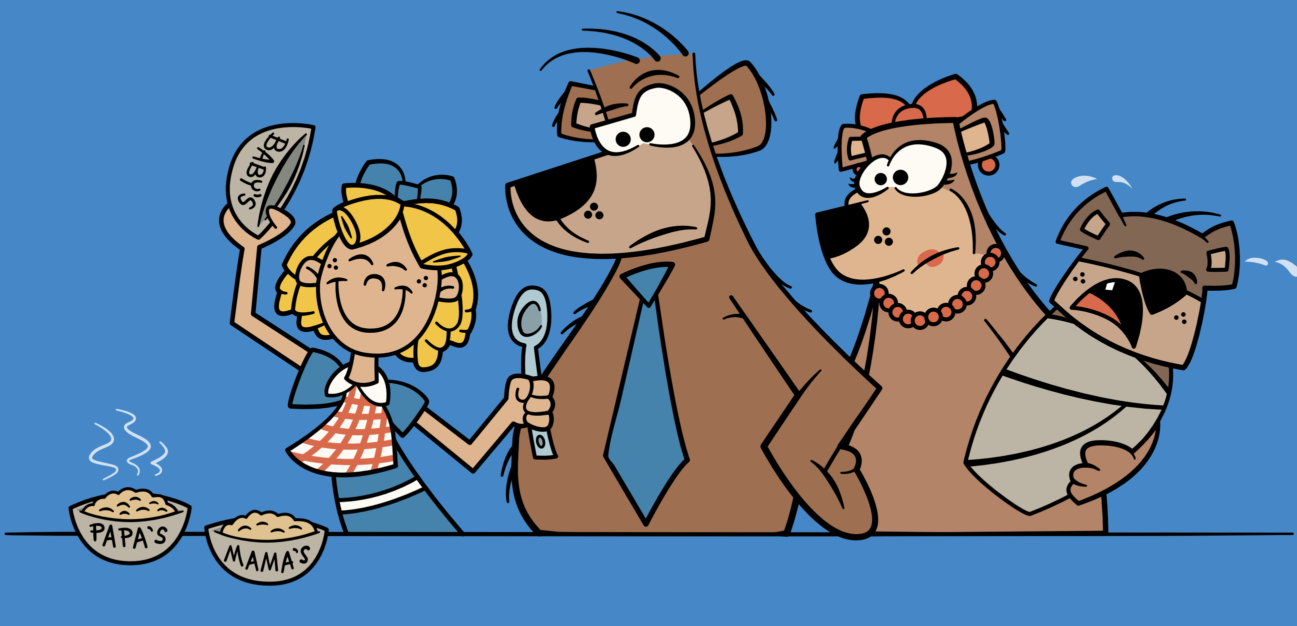
# Summary

With a solid understanding of functions, we no longer need to repeat the same expressions over and over—we can just call the same function with different arguments! In this chapter, we covered a lot, including:

- What a function is, and how it can help us remove duplication from our code.
- What a function parameter is, and how it differs from an argument of a function call.
- The difference between positional and named arguments.
- How to give arguments default values.
- The difference between expression bodies and block bodies.
- How Kotlin will use the **`Unit`** type if we have no meaningful result to return from a function.
- How the `main()` function acts as an entry point to the rest of our code.
- How we can use the `println()` function from the standard library.
- How to use string interpolation to evaluate expressions directly within a string.

Next up, we'll shift gears to learn about *conditionals*—giving our code the ability to make decisions and adapt to different situations.

# Conditionals: When and If



## Different circumstances, different behavior…

In real life, we do different things depending on the circumstances.

For example, if it's raining outside, you'll probably grab an umbrella. If it's sunny outside, you might grab your sunglasses. We do different things depending on the weather.

Similarly, we often need our code to do different things in different situations, so in this chapter, we'll look at Kotlin's *conditionals*.

# Goldilocks and the Three Branches

You might have heard the fairy tale of *Goldilocks and the Three Bears*.

Papa Bear, Mama Bear, and Baby Bear lived in a quaint house nestled in the woods. One day, after preparing some porridge for breakfast, the three bears decided to go out for a leisurely stroll. Meanwhile, a young girl named Goldilocks peeked in through the window and saw three bowls of porridge. Since she was hungry and saw nobody home, she decided to walk inside and taste the porridge for herself.

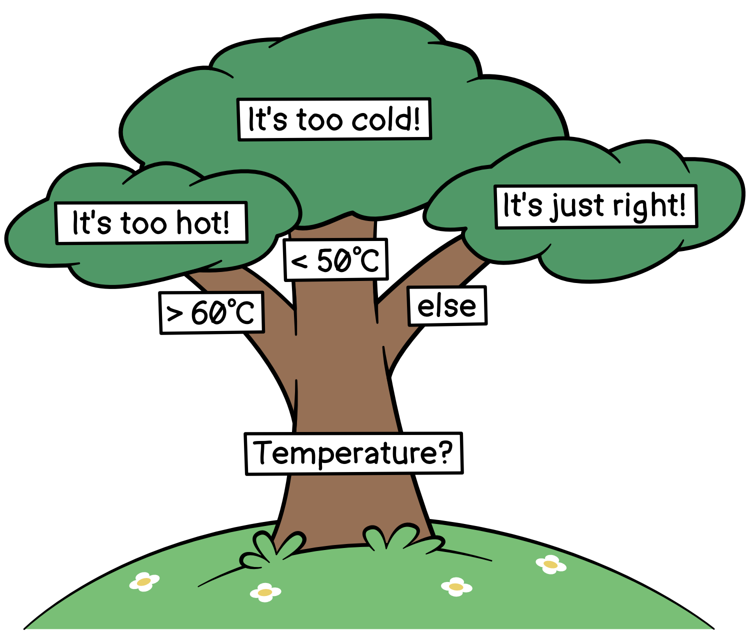
First, she tried Papa Bear's porridge, and exclaimed, "It's too hot!" Then she tried Mama Bear's porridge, and complained, "It's too cold!" Finally, she tried Baby Bear's porridge, and found the temperature to be perfect. "It's just right!" she said, and ate the entire bowl.

Let's map out Goldilocks' three reactions into a simple table. She responds differently depending on the temperature of the porridge.

1. When it's above 60°C, she says, "It's too hot!"
2. When it's below 50°C, she complains, "It's too cold!"
3. But anything in between, and she says, "It's just right!"

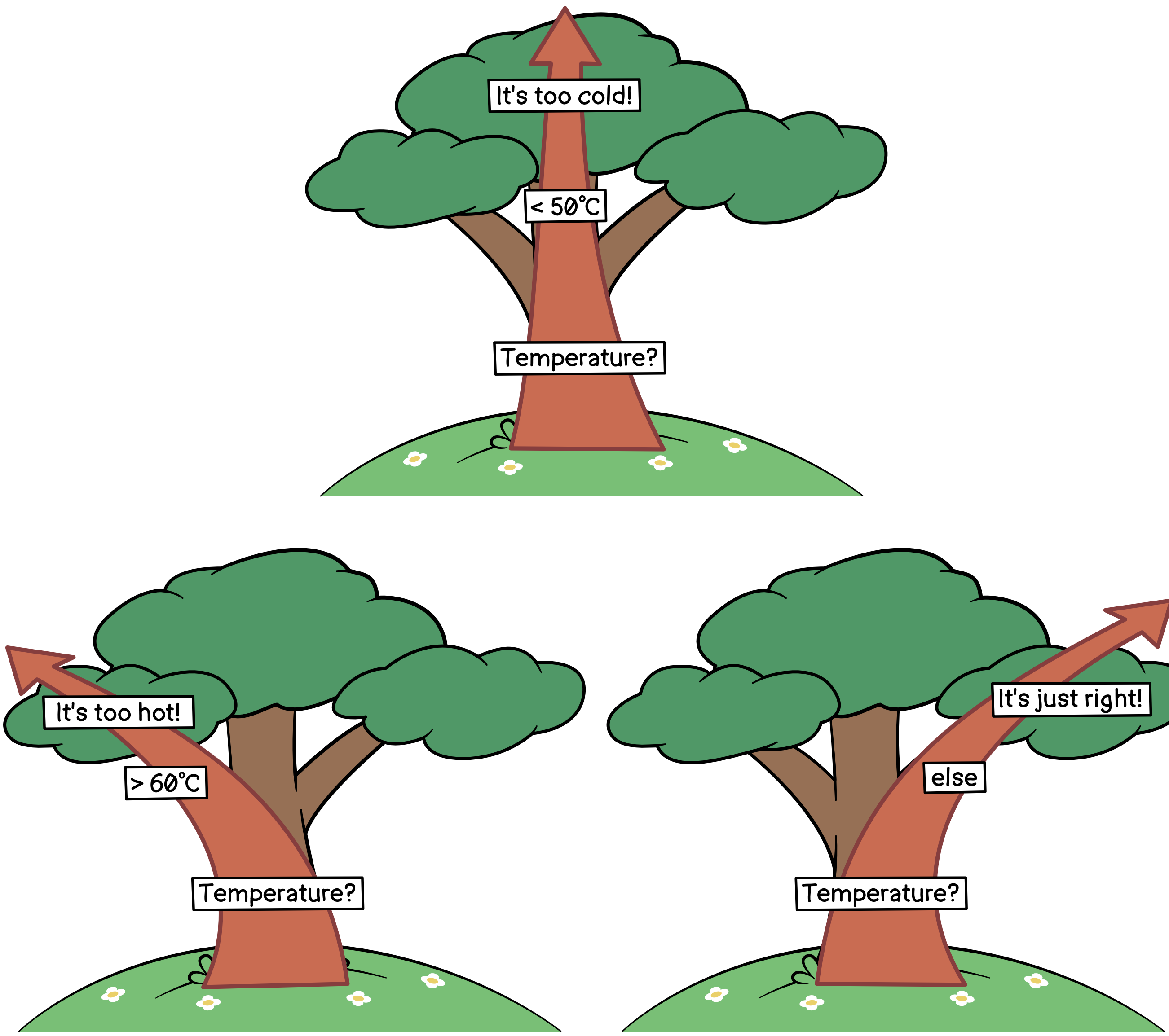
| Temperature | Goldilocks' Reaction |
|---|---|
| Greater than 60°C | "It's too hot!" |
| Less than 50°C | "It's too cold!" |
| Anything else | "It's just right!" |

We can write Kotlin code that will tell us which of these three things Goldilocks will say, based on the temperature of the porridge. In programming terms, the three different cases above—that is, the three different rows of the table—are called **branches**. We can visualize the branches as we'd see on a tree.



So far, when we've run the code that we've written, *every line of code* has run. But now we're going to start writing code where only *one* of the branches will run each time. While the code is running, the *path* that is run—including the particular branch that it takes—is referred to as the **execution path**.

Here we can see the three possible *execution paths* that our Kotlin code could take, depending on the temperature.




Code constructs that choose between different branches (e.g., different responses from Goldilocks) based on some *condition* (e.g., the temperature) are called **conditionals**. Kotlin has a couple of *conditionals* that we can use. Let's take a look!

# Introduction to `when` in Kotlin

Let's look at that table again.

| Temperature | Goldilocks' Reaction |
|---|---|
| Greater than 60°C | "It's too hot!" |
| Less than 50°C | "It's too cold!" |
| Anything else | "It's just right!" |

A table like this is easy to read and understand. We can just scan down the left-hand column, and when we find the temperature of the porridge that Goldilocks is eating, we look to the right to see how she will respond.

Kotlin gives us a powerful conditional called **`when`**, which enables us to basically write that same table in our code. Here's how it looks.

```
val temperature = 53

val reaction = when {
    temperature > 60 -> "It's too hot!"
    temperature < 50 -> "It's too cold!"
    else             -> "It's just right!"
}
```

*Listing 3.1 - A* **`when`** *expression in Kotlin.*

Just to show how similar this is to our table, let's add a little spacing and put the table next to it.

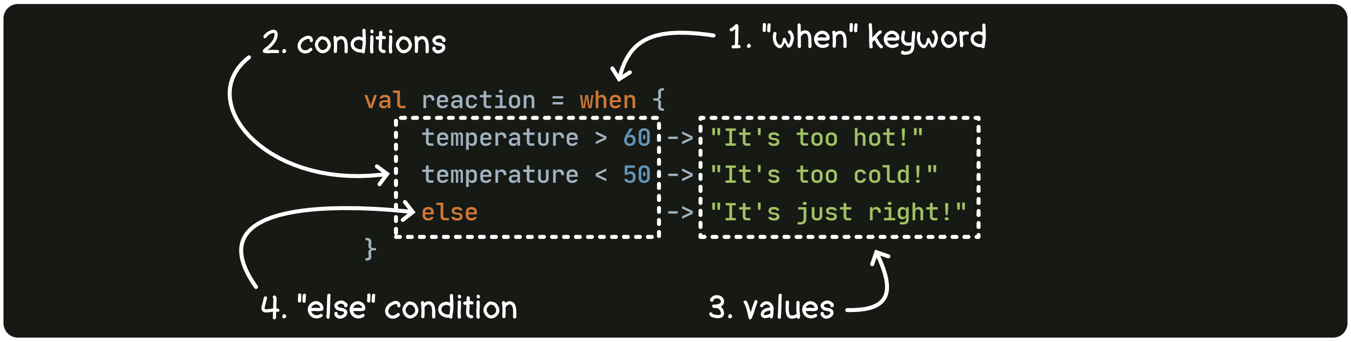
```
val temperature = 53

val reaction = when {

    temperature > 60 -> "It's too hot!"

    temperature < 50 -> "It's too cold!"

    else             -> "It's just right!"

}
```

| Temperature | Goldilocks' Reaction |
|---|---|
| Greater than 60°C | "It's too hot!" |
| Less than 50°C | "It's too cold!" |
| Anything else | "It's just right!" |

This code looks almost identical to the table next to it—each line between the opening brace **`{`** and the closing brace **`}`** is just a row from the table. The **`reaction`** variable will be assigned a *different* value depending on the value of the **`temperature`** variable.

- When the **`temperature`** is greater than 60, then **`reaction`** will be assigned **`"It's too hot!"`**.
- When the **`temperature`** is less than 50, then **`reaction`** will be assigned **`"It's too cold!"`**.
- Otherwise, **`reaction`** will be assigned **`"It's just right!"`**.

To really understand **`when`**, let's look at the different parts.




1. First, there's **`when`**. This keyword tells Kotlin that we want to do something different depending on the circumstances. In this code, notice that **`when`** is an expression, so it is *evaluated* and can be assigned to a variable. In this case, it will evaluate to a string, which will be assigned to the **`reaction`** variable.

2. Next, there are **`temperature > 60`** and **`temperature < 50`**. These are called **conditions**. Conditions are *expressions* that evaluate to a Boolean. The first condition—**`temperature > 60`**—just asks the question, "is the value of the **`temperature`** variable greater than 60?" If so, then it evaluates to **`true`**. Otherwise it evaluates to **`false`**. When we need to compare numbers in Kotlin, we can use **comparison operators** like the greater-than sign **>** or the less-than sign **<**. See the chart below for more information.

3. When the condition evaluates to **`true`**, then the **`when`** expression will evaluate to the *value* on the right side of the arrow **`->`**.

4. At the bottom, we have **`else`**, which is a catch-all branch that's used in case *none* of the conditions above it evaluate to **`true`**.

## Technically Speaking: Comparison and Equality Operators

Sometimes we need to compare one value to another so that we can know whether one value is greater than, less than, or equal to another value. Kotlin gives us a variety of comparison operators that we can use for this purpose.

| Operator | Description | Example |
|---|---|---|
| `<` | Less than | **`x < 5`** |
| `>` | Greater than | **`x > 5`** |
| `==` | Equal to | **`x == 5`** |
| `<=` | Less than or equal to | **`x <= 5`** |
| `>=` | Greater than or equal to | **`x >= 5`** |
| `!=` | Not equal to | **`x != 5`** |

Each of these examples evaluates to a **`Boolean`** value that tells us whether the expression is true. For example, **`x < 5`** evaluates to **`true`** if x is equal to **`2`**, but **`false`** if **`x`** is equal to **`9`**. Technically, **`==`** is called the *equality operator*, **`!=`** is called the *inequality operator*, and the rest are called *comparison operators*.

The `when` expression is quite helpful, so Kotlin developers use it often. It also has some interesting characteristics. Let's look at a few of them now.

## The First True Condition Wins

Goldilocks just found some more porridge in the freezer, so let's add another case for *extremely* cold temperatures.

```
val temperature = -5

val reaction = when {
    temperature > 60 -> "It's too hot!"
    temperature < 50 -> "It's too cold!"
    temperature < 0  -> "It's frigid!"
    else             -> "It's just right!"
}
```

*Listing 3.2 - Adding a fourth branch to a* `when` *expression, for temperatures below zero.*

In this code listing, because the `temperature` variable is set to `-5`, we might expect `reaction` to be `"It's frigid!"`, but it's actually `"It's too cold!"`. Why is that?

Because Kotlin works through the `when` cases from *top to bottom*.

1. First, `temperature > 60` evaluates to `false`, because -5 is not greater than 60.
2. Then, `temperature < 50` evaluates to `true`, because -5 is indeed less than 50.

At this point, Kotlin uses `"It's too cold!"`, because it found a matching condition. So, the third case—`temperature < 0`—is *never evaluated*.

In other words, the first condition that evaluates to `true` will win.

It's easy to make sure that `"It's frigid"` is used when the temperature is below zero. Just put that case *before* the condition where the temperature is below 50 degrees, like in the following example.

```
val temperature = -5

val reaction = when {
    temperature > 60 -> "It's too hot!"
    temperature < 0  -> "It's frigid!"
    temperature < 50 -> "It's too cold!"
    else             -> "It's just right!"
}
```

*Listing 3.3 - Correctly ordering the branches so that the below-zero condition will match.*

Now, when we run this code, the `temperature < 0` case will run *before* `temperature < 50`, so `reaction` will be `"It's frigid!"`.

## Technically Speaking: Switch vs. When

If you've written code in some other languages such as Java or C, you might have used a [`switch` statement]().

One important difference between a `switch` statement and Kotlin's `when` expression is that switch statements have *fall-through*, which means that when one condition matches, all statements below it (even statements for other conditions) will run unless you remember to use a `break` statement.

In Kotlin, `when` has no fall-through, so only *one* case will get executed. However, multiple conditions can point to the same branch, as we'll see in a moment.

## Exact Matches

Sometimes, instead of checking for a *range* of values (e.g., "anything greater than 60", or "anything less than 50") we only need to check for an *exact match*.

After the Three Bears discovered how much Goldilocks liked their porridge, they decided to write a cookbook that includes all of their family recipes. They opened an online store and began selling their books. Since the book is so popular, they wanted to give discounts to people who buy multiple copies of it.

| Quantity Ordered | Price Per Book |
|---|---|
| **1 book** | $19.99 each |
| **2 books** | $18.99 each |
| **3 books** | $16.99 each |
| **4 books** | $16.99 each |
| **5 or more books** | $14.99 each |

We *could* write a `when` expression for this table like this.

```
val quantity = 3

val pricePerBook = when {
    quantity == 1 -> 19.99
    quantity == 2 -> 18.99
    quantity == 3 -> 16.99
    quantity == 4 -> 16.99
    else          -> 14.99
}
```

*Listing 3.4 - A `when` expression with every condition using the equality operator (==).*

However, Kotlin lets us shorten this up even more, by letting us specify a **subject**. Here's how that looks.

```
val quantity = 3

val pricePerBook = when (quantity) {
      1    -> 19.99
      2    -> 18.99
      3    -> 16.99
      4    -> 16.99
      else -> 14.99
}
```

*Listing 3.5 - Using* **when** *with a subject.*

In this example, **quantity** is called the *subject* of the **when** expression. The subject can be any expression, but here we just used the variable **quantity**. Because we used **quantity** as the subject, we no longer had to put "**quantity ==**" in each condition!

There's one more shortcut that Kotlin gives us, allowing us to make this *even* more concise. Since the price-per-book for 3 books is the same as that for 4 books, we can put those conditions on the same line, separated by a comma.

```
val quantity = 3

val pricePerBook = when (quantity) {
      1    -> 19.99
      2    -> 18.99
      3, 4 -> 16.99
      else -> 14.99
}
```

*Listing 3.6 - Separating multiple matching values (3, 4) with a comma.*

## Every Condition Must Be Accounted For

A **when** expression in Kotlin *must* include conditions for *all possible values*. For this reason, we say that a **when** expression must be **exhaustive**. This is also the reason that we usually need to include an **else** condition at the bottom.

Sometimes we can be exhaustive even *without* an **else** condition. For example, consider a Boolean expression. As we saw in Chapter 1, Boolean variables have only two possible values—**true** and **false**.

Kotlin *knows* that a Boolean value can only ever be **true** or **false**. So, as long as we have a branch for both of those conditions, then we won't need an **else** branch.

```
val isLightbulbOn = true

val reaction = when (isLightbulbOn) {
     true  -> "It's bright"
     false -> "I can't see"
}
```

*Listing 3.7 - A* **when** *expression that is exhaustive without an* **else** *branch.*

This isn't the only occasion when we can omit the **else** condition. We'll see this again when we learn about enum classes and sealed types.

## Quick Tip: Aligning when Branches

**when** expressions are a lot easier to read when the conditions, arrows, and values are all lined up into columns, because it makes it easy to visually scan.

To help with this, IntelliJ IDEA and Android Studio include a **code formatter** that will organize the spacing of your **when** expression so that it's consistent. Below you can see how it looks without (left) and with (right) the setting turned on.

```
val reaction = when {
    temperature > 60 -> "It's too hot!"
    temperature < 0 -> "It's frigid!"
    temperature < 50 -> "It's too cold!"
    else -> "It's just right!"
}
```

```
val reaction = when {
    temperature > 60 -> "It's too hot!"
    temperature < 0  -> "It's frigid!"
    temperature < 50 -> "It's too cold!"
    else             -> "It's just right!"
}
```

To turn this on, open the *Settings/Preferences* menu, and then go to *Editor* -> *Code Style* -> *Kotlin*. Pick the *Wrapping and Braces* tab, and then place a check mark next to *Align 'when' branches in columns*. Once you turn this on, you can go to the *Code* menu, and choose *Reformat Code*. The file you have open currently will be reformatted according to the settings, which will now include **when** expressions that are nicely organized and easy to read!

The **when** expression is powerful, and Kotlin developers use it a lot! But it can be a bit heavy-handed for simple Boolean checks like in Listing 3.7 above. For these cases, Kotlin gives us a second kind of conditional.

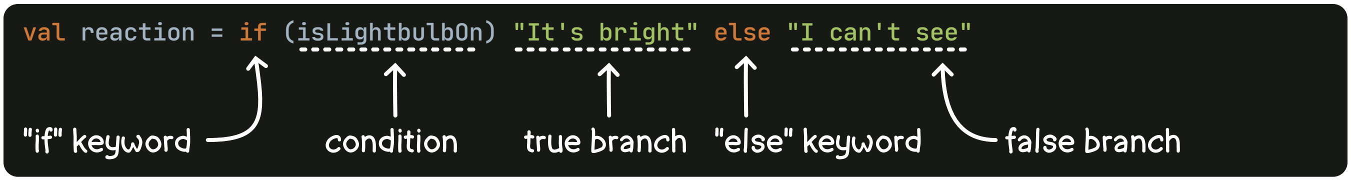
# if Expressions

We can make our lightbulb code even more concise by using an **if** expression instead of a **when** expression. **if** expressions are kind of like **when** expressions, but they have a *single* condition, and two cases—one for **true** and one for **false**. Here's how it looks.

```kotlin
val reaction = if (isLightbulbOn) "It's bright" else "I can't see"
```

*Listing 3.8 - An* `if` *expression in Kotlin.*

Let's break down the parts of an `if` expression.




`if` is a keyword, like `when` and `else`. In the code above, `isLightbulbOn` is the condition that is evaluated.

- If it evaluates to `true`, then `reaction` will be assigned `"It's bright"`.
- If it evaluates to `false`, then `reaction` will be assigned `"I can't see"`.

It's also fine to put the branches on different lines.

```kotlin
val reaction =
    if (isLightbulbOn)
        "It's bright"
    else
        "I can't see"
```

*Listing 3.9 - An* `if` *expression spanning multiple lines.*

We can also use braces `{` and `}` around the branches. Doing so allows us to add *statements* to the branches, as shown below.

```kotlin
var isLightbulbOn = true

val reaction =
    if (isLightbulbOn) {
        isLightbulbOn = false
        "I just turned the light off."
    } else {
        isLightbulbOn = true
        "I just turned the light on."
    }
```

*Listing 3.10 - An* `if` *expression with braces, allowing for statements inside.*

It's *possible* to use `if` for more than one condition. For example, remember our price-per-book lookup in Listing 3.5? We *could* rewrite it into an `if` expression.

```
val pricePerBook =
    if (quantity == 1)
        19.99
    else if (quantity == 2)
        18.99
    else if (quantity == 3)
        16.99
    else if (quantity == 4)
        16.99
    else
        14.99
```

*Listing 3.11 - How **not** to use `if` and `else` in Kotlin.*

If you find yourself doing this, consider using a `when` expression instead. It's easier to read.

## `when` and `if` as Statements

So far, we've used the `when` and `if` conditionals as expressions, but you can also use them as statements. Here's an example of using an if statement in Kotlin.

```
var wattage = 0
var lightbulbIsOn = true

if (lightbulbIsOn) {
    wattage = wattage + 12
}
```

*Listing 3.12 - Using `if` as a statement rather than an expression.*

A few interesting things to note here:

- Unlike conditional expressions, conditional statements do not require an `else` branch. In the example above, if `lightbulbIsOn` is `false`, then the single branch that's there—`wattage = wattage + 12`—will simply never run.
- We did not assign this `if` statement to a variable, because it's not possible to assign a statement to a variable, as we saw in Chapter 1.

## Best Practice: Augmented Assignments

So far, whenever we've needed to change a variable based on its existing value, such as needing to increase `wattage` by 12, we've written it plainly like this: `wattage = wattage + 12`

In Kotlin, there's a shortcut for this, and here's how it looks: `wattage += 12`

In fact, this works with all of the **arithmetic operators** (`+`, `-`, `*`, `/`) that we've used so far:

- `a = a + 1` can be written as `a += 1`.
- `b = b - 2` can be written as `b -= 2`.
- `c = c * 3` can be written as `c *= 3`.
- `d = d / 4` can be written as `d /= 4`.

In Kotlin, it's more common to use this shortcut, so from now on, we'll write it this way.

# Summary

Thanks to conditionals, the Three Bears were able to offer discounts to customers who bought multiple copies of their cookbook. And what became of Goldilocks? Well, she landed a new gig as their official taste tester!

You've already learned a lot about Kotlin—variables, types, expressions, statements, and functions. And in this chapter, you learned all about *conditionals*, including:

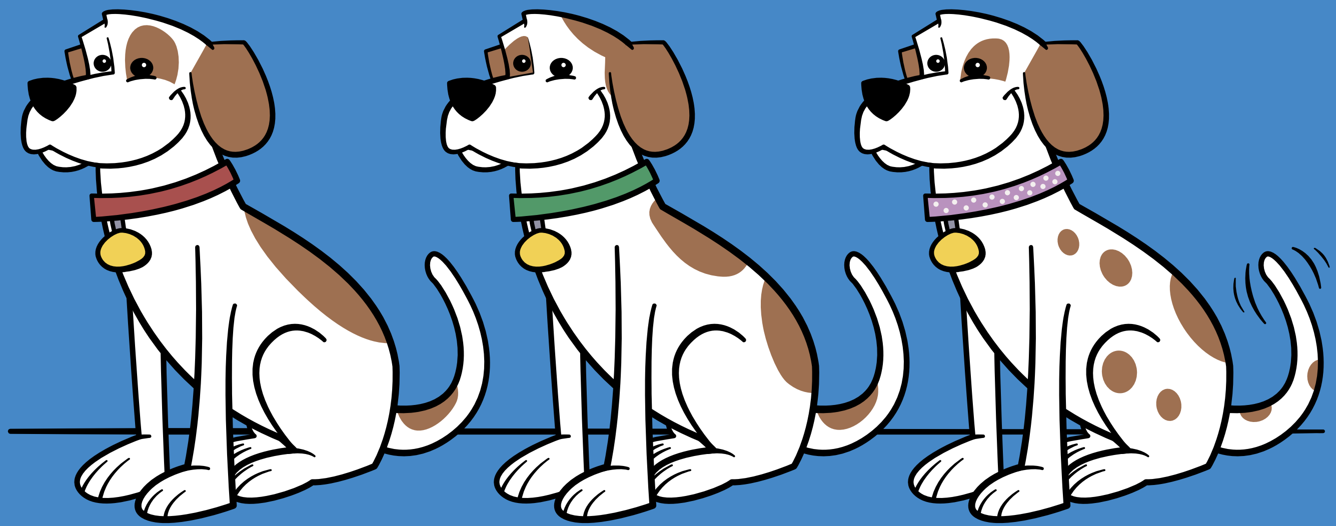
- What branches and conditions are.
- How the `when` expression can be used to pick a different value in different situations.
- How an `if` expression can be a good fit for cases where there are only two branches.
- How `when` and `if` can be used as statements.

In this book, we've used a variety of types, such as integers, strings, and Booleans. In Chapter 4, we'll start putting variables and functions together to create *our very own types*, using *classes* and *objects*—unlocking many exciting possibilities for us to start writing more advanced programs.

Kotlin: An Illustrated Guide

Chapter 4

# Classes, Objects, and Packages



## Let's create our own types!

In Chapter 1, we learned about a variety of *types* in Kotlin, such as **`Double`**, **`String`**, and **`Boolean`**.

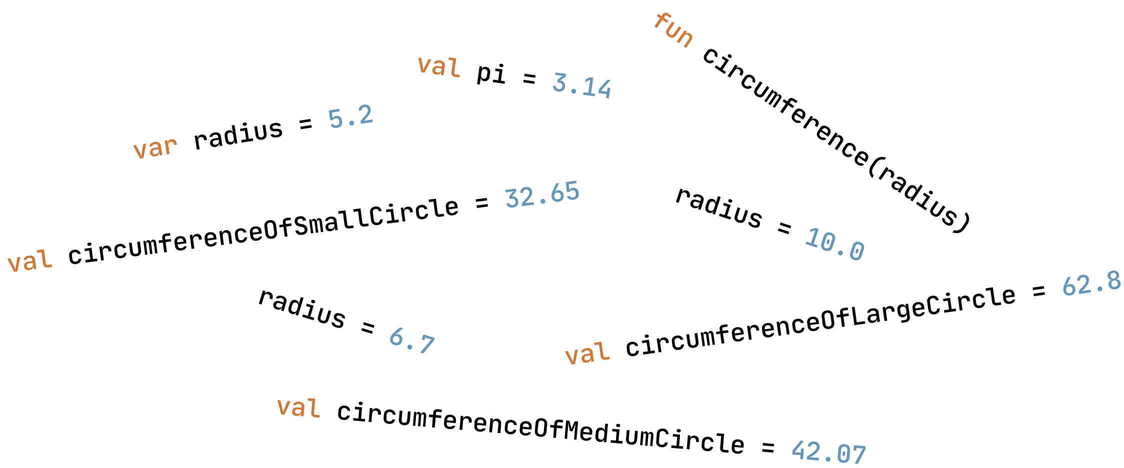
Get ready, because in this chapter, we're going to start creating our *very own* types! We'll put variables and functions together into a *class*.

Let's get started!

# Putting Variables and Functions Together

As you might recall, we started off this book by creating variables to hold things pertaining to a circle, such as its radius and circumference. And in Chapter 2, we created a function to calculate the circumference from the radius.

It all looked kind of scrambled, like this.




This was manageable for such a simple example, but as we come up with more and more things that we want to know about the circle, such as its diameter, area, or position, it can become quite difficult to manage all of those different variables and functions. And once we start introducing other shapes, like rectangles and triangles, it becomes even *harder* to keep things straight—for example, which functions give us the area of a circle, and which give us the area of a rectangle?

So in this chapter, we'll create a new type called a `Circle`. This way, instead of having separate variables and functions that hold a radius and a circumference, we can have a *single* variable that represents the *circle itself*.

So instead of the scrambled variables and functions above, it'll look more like this.

| **smallCircle** | **mediumCircle** | **largeCircle** |
|---|---|---|
| `val pi = 3.14` | `val pi = 3.14` | `val pi = 3.14` |
| `val radius = 5.2` | `val radius = 6.7` | `val radius = 10.0` |
| `fun circumference(radius)` | `fun circumference(radius)` | `fun circumference(radius)` |

In Kotlin, we can put related variables and functions together using a **class**, which is a feature that we will use to create our new `Circle` type.

# Defining a Class

Let's create our very first class, a `Circle`, which will include these variables and functions.

- The `radius` variable.
- The read-only `pi` variable.
- The `circumference()` function.

Instead of jumping into all of this at once, let's build up this class slowly—one step at a time—and look carefully at each part.

## An Empty Class

First, let's define an empty class—with no variables and no functions.

```
class Circle
```

*Listing 4.1 - A simple, empty class in Kotlin.*

This is all it takes to create a new class called `Circle`!

### Best Practice: Naming Classes

In the first three chapters, we created variables and functions, which we named starting with a lowercase letter—for example, `radius` or `area()`. In contrast, classes in Kotlin conventionally start with an uppercase letter—such as `Circle`. If the name has multiple words, each word should begin with a capital letter, such as `CircleShape`.

When we create a class, we're creating a new type, just like `Int`, `Double`, and `String`. In other words, once we define the `Circle` class like this, we can use it anywhere that we'd normally put a type, such as a function parameter.

```
fun draw(circle: Circle) {
  // Code that draws the circle would go here
}
```

*Listing 4.2 - Using our `Circle` class as a function parameter.*

### By the Way: Comments

This is the first time that we've used a **comment** in our code. A section of text that starts with two forward slashes `//` is a *comment*. When Kotlin finds a comment like this, it will ignore the rest of the line, so it has no effect on how the program runs.

Kotlin also supports **block comments**, which begin with `/*` and end with `*/`. These are useful for cases where the comment needs to span multiple lines, or where we want to insert a comment in the middle of the line.

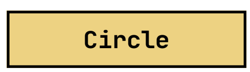
In this book, we'll sometimes use comments to describe parts of the code, or to elide parts that are irrelevant, as we're doing here.

## Our First Diagram

It's often useful to *diagram* our classes, so that we can visualize them and communicate our ideas to friends and coworkers. We'll use diagrams throughout the rest of this book to help explain concepts.

So, as we're building out this **`Circle`** class, we'll also diagram it at each stage, using a diagramming standard called the Unified Modeling Language, or *UML* for short.

We'll start simple. To show a class, just put the name of the class in a box, as we're doing on the left. On the right is the corresponding Kotlin code.




```
class Circle
```

Now that we've got our new **`Circle`** type, we could create a variable to hold it, but since our class is completely empty, it's not particularly useful yet. So, before we do that, let's give our **`Circle`** a **`radius`**!

### Adding a `radius` Property

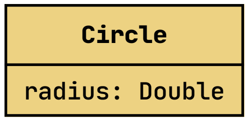
In real life, every circle has a radius, so we need to make sure that every **`Circle`** in our code also has a **`radius`** variable. Here's how we can do that.

```
class Circle(var radius: Double)
```

*Listing 4.3 - Kotlin class with a property.*

In this code, we added a new variable to the class, called **`radius`**, which has a type of **`Double`**. The value of **`radius`** can be changed, because of the var that comes before it. In Kotlin, a variable in a class like this is called a **property** of the class.

Let's also update our diagram to show that a **`Circle`** class has a **`radius`** property. To do this, we draw a horizontal line under the name of the class, and write out the name of the property and its type, almost identically to how we write it in our Kotlin code.




```
class Circle(var radius: Double)
```

Now that we've got a circle class with a radius, we're ready to start using it!

# Objects

In this book, we've already created lots of variables. For example, here's how we can declare and assign a variable with a `Double` type.

```
val radiusOfSmallCircle: Double = 5.2
```

*Listing 4.4 - Creating a variable that holds a* `Double`*.*

As mentioned, when we created the class, we made a new type called `Circle`. Just like you can have a variable that's a `Double` type, you can also have a variable that's a `Circle` type. Declaring and assigning a `Circle` variable is easy.

```
val smallCircle = Circle(5.2)
```

*Listing 4.5 - Creating a variable that holds a* `Circle`*.*

This creates a new variable called `smallCircle`, which is assigned a `Circle` with a radius of `5.2`.

Keep in mind—just as we can have many different `Double` values like…

- `5.2`
- `6.7`
- `10.0`

… we can also have lots of different `Circle` values like…

- A circle with a radius of `5.2`.
- A circle with a radius of `6.7`.
- A circle with a radius of `10.0`.

But when it comes to classes, instead of calling these *values*, we usually call them **objects**.

## Constructing Objects

Let's look at that code again.

```
// Declaring the class
class Circle(var radius: Double)

// Using the class
val smallCircle = Circle(5.2)
```

What's happening when we write **`Circle(5.2)`**?

It's kind of like we're calling a function named **`Circle()`** that has a parameter called **`radius`** and a return type of **`Circle`**. These kinds of functions aren't called *functions*, though. They're called **constructors** because they *construct* a new object.

## Constructor Parameters

Note that when you call a constructor, you must provide an argument for every property that is listed between the constructor's opening and closing parentheses—**`(`** and **`)`**. Since we put **`var radius: Double`** between those parentheses, we have to provide an argument of type **`Double`** when we call the constructor.

```
class Circle(var radius: Double)

val smallCircle = Circle(5.2)
```

Note that **`radius`** is actually filling two roles.

1. It's a **constructor parameter**. We have to provide a value for it whenever we call the constructor. (However, just like with function parameters, we can also give a constructor parameter a default argument).

2. It's a *property*. We'll be able to get the value of the *radius* from any circle object. We'll see an example of this in a moment.

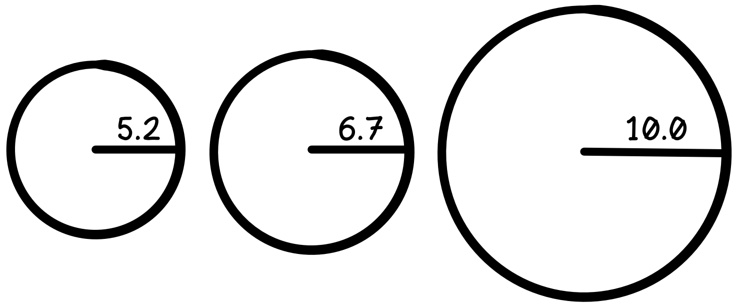
When we *create* an object, we say that you're creating an **instance** of the class. For that reason, creating an object is sometimes referred to as **instantiating** the class.

## Classes vs. Objects

The difference between classes and objects can be confusing at first, so let's take a moment to clarify it.

A *class* describes the *characteristics and behavior* of some concept. If we're talking about circles, those characteristics might include its radius, diameter, circumference, and area.

An *object* is an actual, particular *instance* of that thing. Here are three circle *objects*.




A circle *class* answers questions such as these.

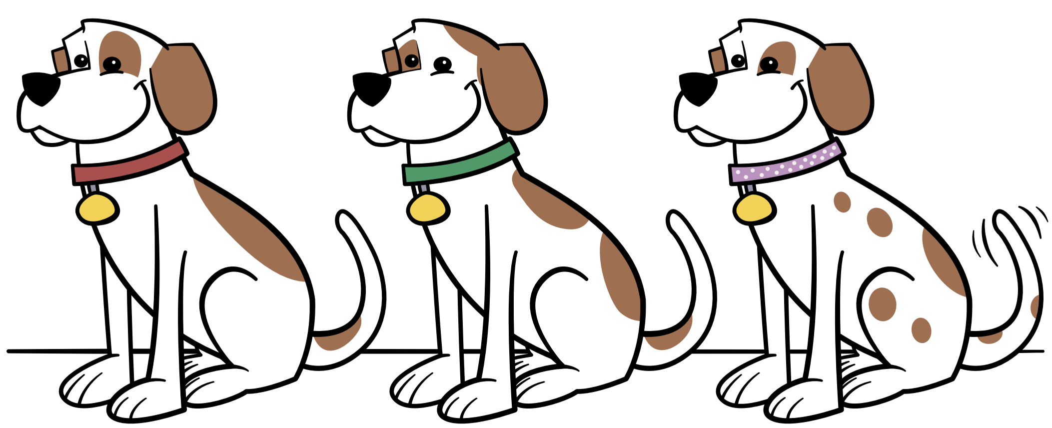
- "What does it mean for something to be a circle?"
- "What characteristics does it have?"
- "What does it do?"

A circle *object* answers questions like these.

- "What is the radius of this *particular* circle?"
- "What is its circumference?"
- "What is its area?"

Here are a few more examples to help distinguish between classes and objects.

- We might have a *Number* class, with objects like 32,768 or 6.62607015.
- We might have a Color class, with objects like red, green, and blue.
- We might have a Dog class, with objects like Fido, Rover, or Mrs. Wagglytails.



We'll see plenty more examples of classes and objects throughout the rest of this book!

## Getting a Property's Value

Now that we've created a circle object, how can we get its radius?

Easy—to get the value of a property on an object, type the name of the *variable*, *a dot*, and the name of the *property*, like this.

```
val smallCircle = Circle(5.2)
val radiusOfSmallCircle: Double = smallCircle.radius
```

*Listing 4.6 - Getting the value of* `radius`.

The dot character here is known as the **access operator**, or more casually, the **dot operator**.

After running that code, `radiusOfSmallCircle` will be equal to `5.2`. That takes care of `radius`. It's time to move onto the other property, `pi`.

## Read-Only Properties

We *could* put `pi` inside the parentheses like we did for `radius`, separating them with a comma.

```
class Circle(var radius: Double, val pi: Double)
```

*Listing 4.7 - Adding a second property, which you'll have to provide when calling the constructor.*

But if we do this, then we'd have to provide `pi` *every time* we instantiate a circle!

```
val smallCircle = Circle(5.2, 3.14)
val mediumCircle = Circle(6.7, 3.14)
val largeCircle = Circle(10.0, 3.14)
```

*Listing 4.8 - Providing the value of the* `pi` *property when calling the constructor.*

That's not quite what we want. Since **pi** should *always* be the exact same value regardless of the particular circle, it doesn't make sense for it to be a constructor parameter. In fact, it would be better if the calling code could *never* specify the value of `pi` when constructing a `Circle`.

To do that, we can simply move `pi` out of the parentheses, so that it looks like this.

```
class Circle(var radius: Double) {
  val pi: Double = 3.14
}
```

*Listing 4.9 - A class with a body. It has two properties but only one constructor parameter.*

Here, we added an opening brace `{` and a closing brace `}`. Everything between those braces is called the **body** of the class. Inside of the body, we declare `pi`, and assign it a value of `3.14`.

By moving it out of the parentheses, the `pi` property is no longer a constructor parameter, so we can continue to call the constructor with just the radius, as we did back in Listing 4.5:

```
val smallCircle = Circle(5.2)
```

*Listing 4.10 - We no longer have to pass a second argument to the constructor.*

## Private Properties

As it's currently written, we can take any `Circle` object and get the value of both `radius` and `pi`.

```
val smallCircle = Circle(5.2)

val radiusOfSmallCircle = smallCircle.radius
val piFromSmallCircle = smallCircle.pi
```

*Listing 4.11 - Getting the values of the* `radius` *and* `pi` *properties.*

There aren't too many reasons why code *outside* of the class would need the value of `pi`. Let's make it so that this property is *only* visible from *inside* the class. To do that, we'll add the keyword `private` when we declare it.

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14
}
```

*Listing 4.12 - Making* `pi` *private, so that it is only visible from within the class body.*

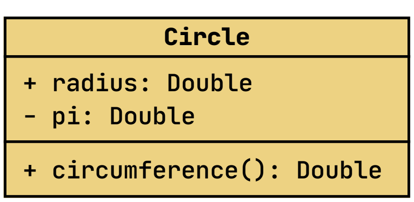
Now, if we try to get the value of the `pi` property from *outside* of the class body, we'll get an error.

```
val smallCircle = Circle(5.2)

val radiusOfSmallCircle = smallCircle.radius
val piFromSmallCircle = smallCircle.pi
```

*Listing 4.13 - **Error:** "Cannot access 'pi': it is private in 'Circle'" (does not compile).*

Let's update our UML class diagram to include the `pi` property. We can indicate the *visibility* of a property in the diagram.

- Private properties are preceded with a **-** symbol.
- Public properties are preceded with a **+** symbol.




```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference() = 2 * pi * radius
}
```

`private` is one of a handful of keywords that can be used to tell Kotlin how "visible" we want a property or function to be. By marking `pi` with `private`, we made it so that it is only visible inside the body of the class. Any code outside of the class can't see that property.

A keyword that changes the characteristics of a declared class, property, or function is called a **modifier**. Since the `private` modifier controls the *visibility*, it's specifically known as a **visibility modifier**. We'll see other kinds of modifiers later in this book as we explore other kinds of classes and types.

If we don't use a visibility modifier, as is the case with `radius`, then it's the same thing as marking it as `public`, which means that we can see that property or function anywhere.

There are two other visibility modifiers—`protected` and `internal`.

- We'll look at `protected` in detail in Chapter 14, once we learn about at subclasses.
- We won't cover `internal` in this book, but it's used to restrict the visibility to a single library of code.

Now, we're ready to add the `circumference()` function to the class!

## Adding a Member Function

When a function belongs to a class, it's often called a **method** or **member function**. Adding a method to a class is easy—simply put it into the body of the class. To start with, let's just take the exact same function from Listing 2.3, and drop it verbatim into our `Circle` class.

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference(radius: Double) = 2 * pi * radius
}
```

*Listing 4.14 - Adding the* `circumference()` *function.*

When first we created the `circumference()` function back in Chapter 2, it made sense for it to have a *parameter* named `radius`. But now that we're adding this function to the *class*, we can just refer to the value of the `radius` *property* instead.

In other words, instead of referring to the `radius` *parameter*, like this…

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference(radius: Double) = 2 * pi * radius
}
```

… we can remove the **radius** parameter from the function, so that it refers to the *property*, like this.

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference() = 2 * pi * radius
}
```

This introduces the concept of *scope*, which we will explore in depth in Chapter 11. For now, just be sure to *remove the parameter* from the **circumference()** function so that **2 * pi * radius** will refer to the **radius** *property*.

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference() = 2 * pi * radius
}
```

*Listing 4.15 - Removing the* **radius** *parameter from the* **circumference()** *function.*

Now that **Circle** has a **circumference()** function, how can we call it?

Calling a function on an object is done similarly to how we got the value of **radius**: the name of the *variable*, a dot, and the name of the *function*.

```
val smallCircle = Circle(5.2)
val circumferenceOfSmallCircle = smallCircle.circumference()
```

*Listing 4.16 - Calling a function on an object.*

Before we move on, let's add **circumference()** to our diagram!

| Circle |
| --- |
| + radius: Double<br>- pi: Double |
| + circumference(): Double |

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference() = 2 * pi * radius
}
```

Note that the diagram does not include the *body* of the function. In other words, **2 * pi * radius** does not appear in it. That's because class diagrams are designed to give you an idea of what data and behavior are a part of the class, without going into the specifics.

## Adding More Functions

When we started off this chapter, we only had a **`radius`** variable and a **`circumference()`** function. Now that we've put those two things together into a class, it's time to fill out our **`Circle`** class with other things that we might want to know about a circle.

For example, we can add a function that calculates the *area* of the circle.

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference() = 2 * pi * radius
  fun area() = pi * radius * radius
}

val smallCircle = Circle(5.2)
val areaOfSmallCircle = smallCircle.area()
```

*Listing 4.17 - Adding a second function to our class, and calling that function.*

We can also add a function to calculate its *diameter*.

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference() = 2 * pi * radius
  fun area() = pi * radius * radius
  fun diameter() = 2 * radius
}

val smallCircle = Circle(5.2)
val diameterOfSmallCircle = smallCircle.diameter()
```

*Listing 4.18 - Adding a third function to our class, and calling it.*

And, we can even call the **`diameter()`** function from inside **`circumference()`**.

```
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference() = diameter() * pi
  fun area() = pi * radius * radius
  fun diameter() = 2 * radius
}
```

*Listing 4.19 - Rewriting the **`circumference()`** function so that it uses the **`diameter()`** function.*

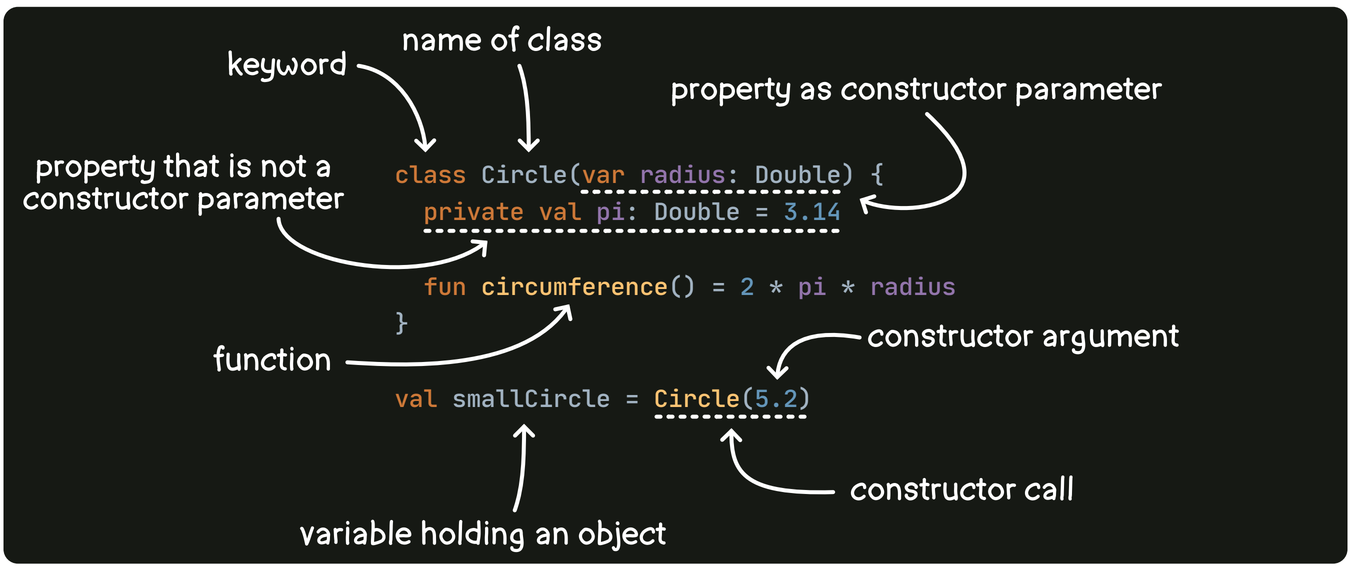
And now, we can add these last few functions to our UML diagram.

```
Circle
+ radius: Double
- pi: Double
+ circumference(): Double
+ area(): Double
+ diameter(): Double
```

```kotlin
class Circle(var radius: Double) {
  private val pi: Double = 3.14

  fun circumference() = diameter() * pi
  fun area() = pi * radius * radius
  fun diameter() = 2 * radius
}
```

## Anatomy of a Class

Now that we've covered the basics of Kotlin classes, here's a recap of the main pieces.




There are a few important terms to know before we move on.

- Properties and functions declared *within a class* are regarded as **members** of the objects created from that class.
- Variables and functions that are declared *within a function* are said to be **local** to that function, because you can only use them inside that function's body.
- The term **top-level** is used to refer to a variable or function that is *neither* a member of a class *nor* declared within a function.

# Everything is an Object

Up until this chapter, we've only used built-in Kotlin types, such as `Double`, `String`, and `Boolean`. You might be surprised to learn that when we used those types, we were actually using classes and objects! Just like we used the dot to get properties and call functions on our `Circle` objects, we can also use a dot on any of these types. Let's look at a few examples of member functions and properties on types that we've seen before.

## Doubles as Objects

Objects of type `Double` have functions like `plus()` and `times()`. So instead of writing our `circumference()` function like this…

```
fun circumference() = 2 * pi * radius
```

*Listing 4.20 - The* `circumference()` *function, using arithmetic operators.*

… we can instead write it like this.

```
fun circumference() = 2.times(pi).times(radius)
```

*Listing 4.21 - The* `circumference()` *function, using function calls.*

Kotlin developers normally use the *arithmetic operators* (`+`, `-`, `*`, `/`) in most cases, but the functions are there if you want them!

## Strings as Objects

`String` objects also have some interesting properties and functions. Here are a few examples.

- The `length` property tells you how many characters (i.e., letters, numbers, and symbols) are in the string.
- `uppercase()` will force all of the letters in the string to upper case.
- `drop()` will remove characters from the beginning of the string.

Here's how that looks in code.

```
val greeting: String = "Welcome"

val numberOfLettersInGreeting = greeting.length // Evaluates to 7
val loudGreeting = greeting.uppercase()          // Evaluates to "WELCOME"
val substring = greeting.drop(3)                 // Evaluates to "come"
```

*Listing 4.22 - Getting a property and calling functions on a* `String` *object.*

## Booleans as Objects

Even `Boolean` variables—which are only ever `true` or `false`—are objects! For example, if you want to turn on the headlights of your car if *either* it's dark *or* it's raining, you can write code to do that like this.

```kotlin
val isDark: Boolean = true
val isRaining: Boolean = false

val shouldTurnOnHeadlights = isDark.or(isRaining)
val shouldStayHome = isDark.and(isRaining)
```

*Listing 4.23 - Calling functions on a* **`Boolean`** *object.*

## Best Practice: Boolean Functions and Operators

Although it's possible to use functions like **`or()`** and **`and()`** on a Boolean variable, it's usually a better idea to use the operators **`||`** and **`&&`** instead, like this:

```kotlin
val shouldTurnOnHeadlights = isDark || isRaining
val shouldStayHome = isDark && isRaining
```

The fancy words for **`||`** and **`&&`** are **disjunction operator** and the **conjunction operator**, respectively, but almost all programmers just call them "or" and "and". The reason to favor the operators over the function calls has to do with a concept called **short-circuiting**, and here's how it works.

- When using **`||`**, if the expression on the left evaluates to **`true`**, Kotlin knows that the result of the whole thing must be **`true`**, so it won't bother evaluating the expression on the right.
- When using **`&&`**, if the expression on the left evaluates to **`false`**, Kotlin knows that the result of the whole thing must be **`false`**, so it won't bother evaluating the expression on the right.

When we're just writing a simple case like above, where we've got two **`Boolean`** variables, this won't make much of a difference, but if we've got a function call that takes a long time to calculate its result this could be a big deal.

```kotlin
val shouldGetRaise = yearsOfService > 1 && calculateSalary() < maximumSalary
```

Boolean values, conjunction, and disjunction are all part of the wonderful world of Boolean algebra.

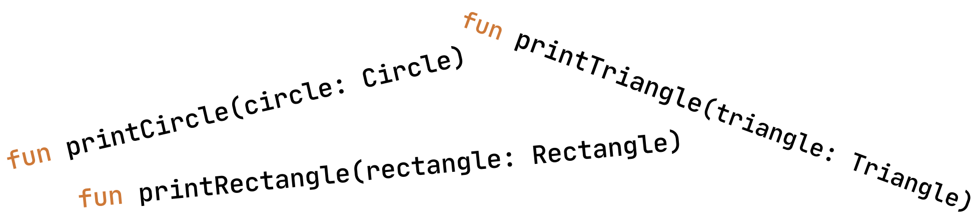
# Single-Instance Objects

Let's imagine that we've created classes for a few more shapes, such as triangles and rectangles. If we want a function that prints each kind, we could end up with lots of functions that aren't grouped together in any way.

```
fun printCircle(circle: Circle) =
    println("This circle has a radius of ${circle.radius}")

fun printTriangle(triangle: Triangle) =
    println("This triangle has an area of ${triangle.area}")

fun printRectangle(rectangle: Rectangle) =
    println("This rectangle has a perimeter of ${rectangle.perimeter}")
```

*Listing 4.24 - Three different functions, each printing a property of a different shape.*

Much like at the beginning of this chapter, we end up with multiple functions that are related, but there's nothing grouping them together.




Of course, we could use a class to group them, as we did with **`Circle`** back in Listing 4.19.

```
class ShapePrinter {
    fun printCircle(circle: Circle) = ...
    fun printTriangle(triangle: Triangle) = ...
    fun printRectangle(rectangle: Rectangle) = ...
}

val printer = ShapePrinter()
val circle = Circle(5.2)
printer.printCircle(circle)
```

*Listing 4.25 - Grouping the three functions into a class.*

This certainly works, but there are some important differences between the **`Circle`** class and this **`ShapePrinter`** class.

For example, it made sense for a **`Circle`** to be a class, because each instance might have a different **`radius`** value. However, **`ShapePrinter`** has no constructor parameters. In fact, we could easily imagine just using the same, single instance of **`ShapePrinter`** everywhere throughout our code.

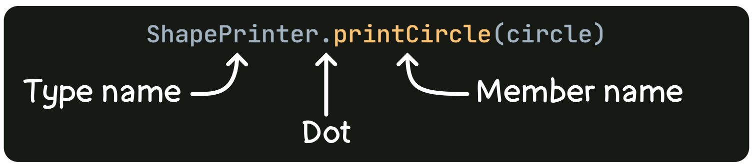
For cases like this, instead of defining this as a class and then instantiating it into an object, we can simply declare it as an object *directly*.

To do this, we can use the **`object`** keyword rather than the **`class`** keyword.

```
object ShapePrinter {
    fun printCircle(circle: Circle) = ...
    fun printTriangle(triangle: Triangle) = ...
    fun printRectangle(rectangle: Rectangle) = ...
}

val circle = Circle(5.2)
ShapePrinter.printCircle(circle)
```

*Listing 4.26 - Grouping the three functions into a single-instance object.*

When we define an object with the **`object`** keyword, there will only ever be a *single* instance of that object. In many programming languages, this is known as a **singleton**. As demonstrated in the code above, a function or property in a singleton can be called by using its type name, a dot, and the name of the member.

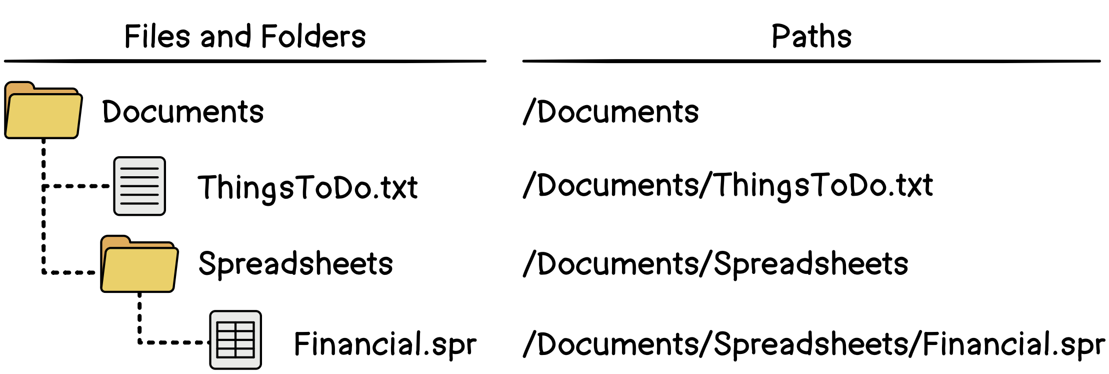



Note that there's no constructor for us to call here, because it's an *object* rather than a *class*. Types declared with the **`object`** keyword can have properties, but they can't have *constructor* properties, because there's no constructor for us to call!

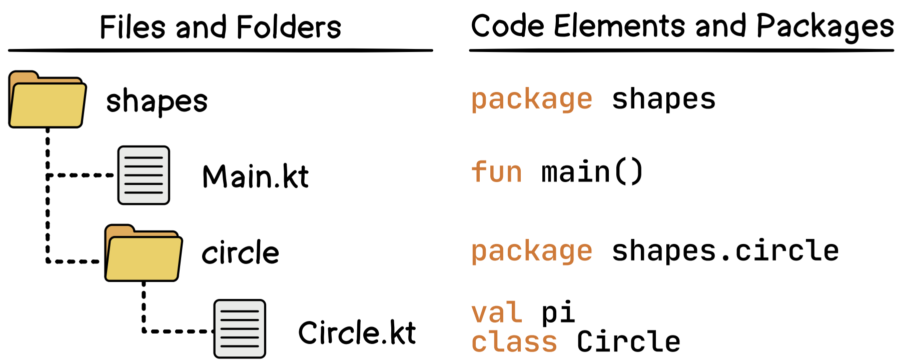
# Grouping into Packages

We've seen how we can group properties and functions into *classes* and *singleton objects*. However, it doesn't end here—we can group our code even further!

When we look at the contents of a computer's hard drive, we'll see lots of different files. To keep these files organized, they're also separated into folders. We might even include one folder *inside* of another folder. This structure creates a hierarchy that keeps related files together, making it easier for us to know where to look when we're trying to find a file.



Similarly, our Kotlin code can be broken up into separate files and folders. Whereas *files* and *folders* are a concept that applies to the computer's operating system, Kotlin deals with the concepts of **code elements**—things like variables, functions, objects, and classes—and **packages**.




Generally, there's a one-to-one relationship between a project's *folders* and its *packages*. When we spread out our Kotlin code across different folders, we should also indicate the package that corresponds to its folder. Package names are similar to the folder paths in the operating system, but instead of separating them with slashes, we separate them with dots.

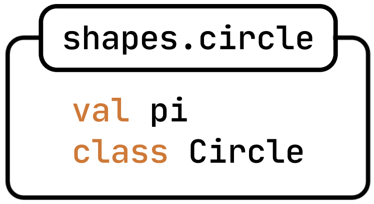
| Path | Corresponding Package |
|---|---|
| /shapes | `shapes` |
| /shapes/circle | `shapes.circle` |
| /shapes/rectangle | `shapes.rectangle` |
| /shapes/triangle | `shapes.triangle` |

To indicate the package name for a Kotlin file, use the keyword **`package`** followed by the name of the package. For example, if our **`Circle`** class is in a file in the **`/shapes/circle`** folder, then at the top of the file, it should include "**`package shapes.circle`**".

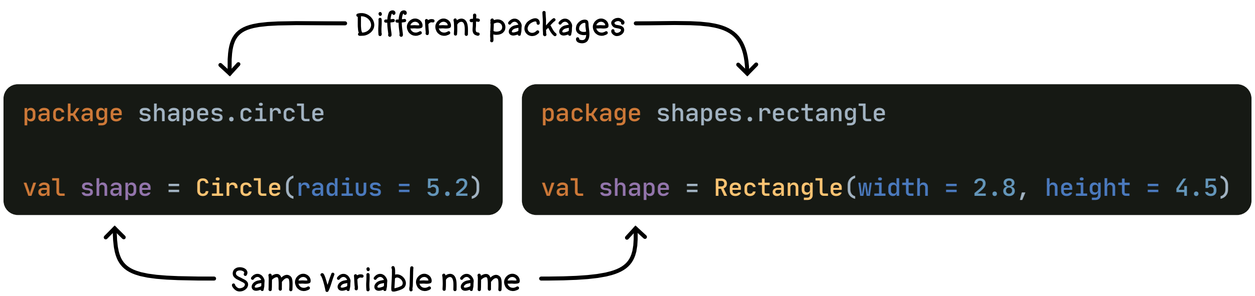
```kotlin
package shapes.circle

val pi: Double = 3.14

class Circle(var radius: Double) {
  fun circumference() = diameter() * pi
  fun area() = pi * radius * radius
  fun diameter() = 2 * radius
}
```

*Listing 4.27 - Adding a package header.*

By adding this line, all of the code elements within that file will be included in the **`shapes.circle`** package.




One of the nice things about packages is that we can have *multiple* code elements with the *same* name in *different* packages.

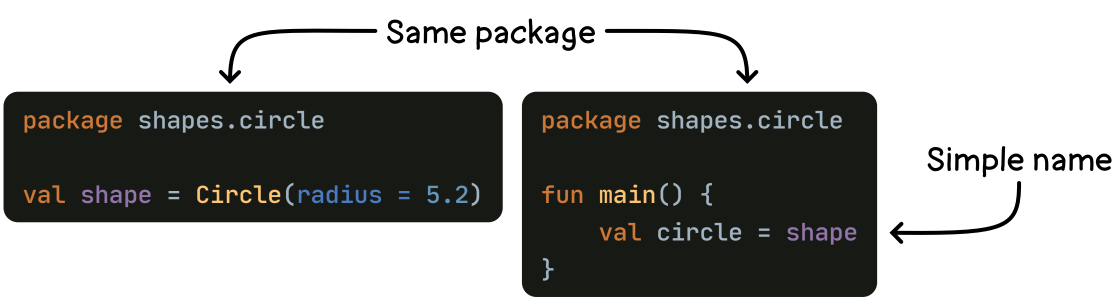



If two code elements can have the same name, how can Kotlin distinguish between them?

## Qualifying Code Elements

Until we started explicitly declaring the packages, all of our code elements were in the same default package. When an element is *declared* in the same package where we're *using* it, we can just refer to it with its simple name.

For example, let's say our **shape** variable is in the same package as our `main()` function. In that case, we can simply refer to it as **shape**.




However, if we want to use a code element that's declared in a *different* package, we'll need to *qualify* its name to clarify exactly which one we're talking about. For example, if we move the `main()` function into the **shapes** package instead of the `shapes.circle` package, we can refer to it by using its **fully-qualified name**, which includes its full package name, a dot, and its simple name.

```
package shapes

fun main() {
    val circle = shapes.circle.shape
}
```

Fully-qualified name

In this code, you might have noticed that the **shape** variable is in a deeper package within the **shapes** package, where the **main()** function resides. In cases like this, rather than using the fully-qualified name, we can use a **partially-qualified name**, which looks like this.

```
package shapes

fun main() {
    val circle = circle.shape
}
```

Partially-qualified name

Writing out qualified names can be a lot of typing, and they can take up a lot of space in the code, so let's look at a more common way to use code elements from other packages.

## Importing Code Elements

Rather than qualifying a code element everywhere that we use it, we can **import** it at the beginning of the file.

For example, let's import the **shape** variable from the **shapes.circle** package. To import a code element, simply use the keyword **import** and its fully-qualified name. Imports are placed *after* the package declaration and *before* the rest of your code in the file, as seen here.

```
package shapes

import shapes.circle.shape

fun main() {
    val circle = shape
}
```

*Listing 4.28 - Adding an import directive.*

By importing **shape** from the **shapes.circle** package, we no longer need to qualify the name when we use it.

### Named Imports

In some cases, we might want to import two code elements that have the same name. For example, if we try to import **shape** from both the **shapes.circle** and the **shapes.rectangle** packages, we'll get an error.

```
package shapes

import shapes.circle.shape
import shapes.rectangle.shape

fun main() {
    val myShape = shape
}
```

Which of these two should this refer to?

In these cases, we can use a **named import** for one or both of the elements we're importing, which effectively gives the element an alias in that file. For example, let's use a named import for **`shapes.circle.shape`**.

```
package shapes

import shapes.circle.shape as circle
import shapes.rectangle.shape

fun main() {
    val myShape = circle
    val myOtherShape = shape
}
```

Named import

## By the Way: What Else Can Be Imported?

So far, we've only imported a top-level variable, but it's also possible to import top-level functions, classes, singleton objects, and even the individual members of a singleton object.

## Wildcard Imports

In bigger projects, it's not unusual for a file to include a long list of imports. If you find yourself importing lots of elements from the same package, you can use a **wildcard import** instead. For example, we might need to import **`Circle`**, **`shape`**, and **`pi`** from the **`shapes.circle`** package. We could import all three of them, like this.

```
package shapes

import shapes.circle.Circle
import shapes.circle.shape
import shapes.circle.pi

fun main() {
    println(Circle(1.9).radius)
    println(shape.radius)
    println(pi)
}
```

*Listing 4.29 - Importing three code elements from the same package.*

However, we can also use an asterisk `*` wildcard.

```
package shapes

import shapes.circle.*

fun main() {
    println(Circle(1.9).radius)
    println(shape.radius)
    println(pi)
}
```

*Listing 4.30 - Importing all of the code elements from the* **`shapes.circle`** *package.*

Just be mindful that wildcards make it easy to import more than you expect, and could result in naming collisions that you might not have anticipated. In fact, some developers prefer never to use wildcard imports at all!

## Importing from the Standard Library

Packages and imports aren't useful just for your own code—sometimes they're needed when using functions or types from Kotlin's standard library. For example, the standard library includes its own definition of pi, so we don't have to define it ourselves.

We can update our **`Circle`** class to use Kotlin's pi like this.

```
import kotlin.math.PI

class Circle(var radius: Double) {
    fun circumference() = diameter() * PI
    fun area() = PI * radius * radius
    fun diameter() = 2 * radius
}
```

*Listing 4.31 - Importing the constant for pi from Kotlin's standard library.*

### Technically Speaking: Constants

When we created our own variable for pi, we wrote its name in lowercase, but you might have noticed that we had to change to an uppercase name when we used pi from the standard library. Top-level variables that hold a number, Boolean, or a string can also be marked as a **constant** by using the keyword **`const`**. By convention, a constant is named with all uppercase letters.

```
const val ONE = 1
```

> Since the standard library's pi variable is a constant, it's written with all uppercase letters.
>
> Within the same project, the Kotlin compiler treats constants as inline values wherever you reference them, so using the `ONE` constant above is the same as literally writing out the value `1` at each call site.

In fact, even `println()` is defined in a package named `kotlin.io`. However, we don't have to import `println()` because Kotlin *automatically* imports everything from the `kotlin.io` package, as well as a few other packages in the standard library.

Most of the code in this book is focused and self-contained such that we usually won't need to declare packages or imports. It's important to know about them, though, because they're very frequently needed in real-world projects.

# Summary

Classes are powerful, and even though we covered a lot of ground in this chapter, we've really only introduced them. They open up a whole new world of ways to represent concepts in our code. Later in this book, we'll cover more advanced concepts related to classes, such as inheritance.

Here's what we learned in this chapter:

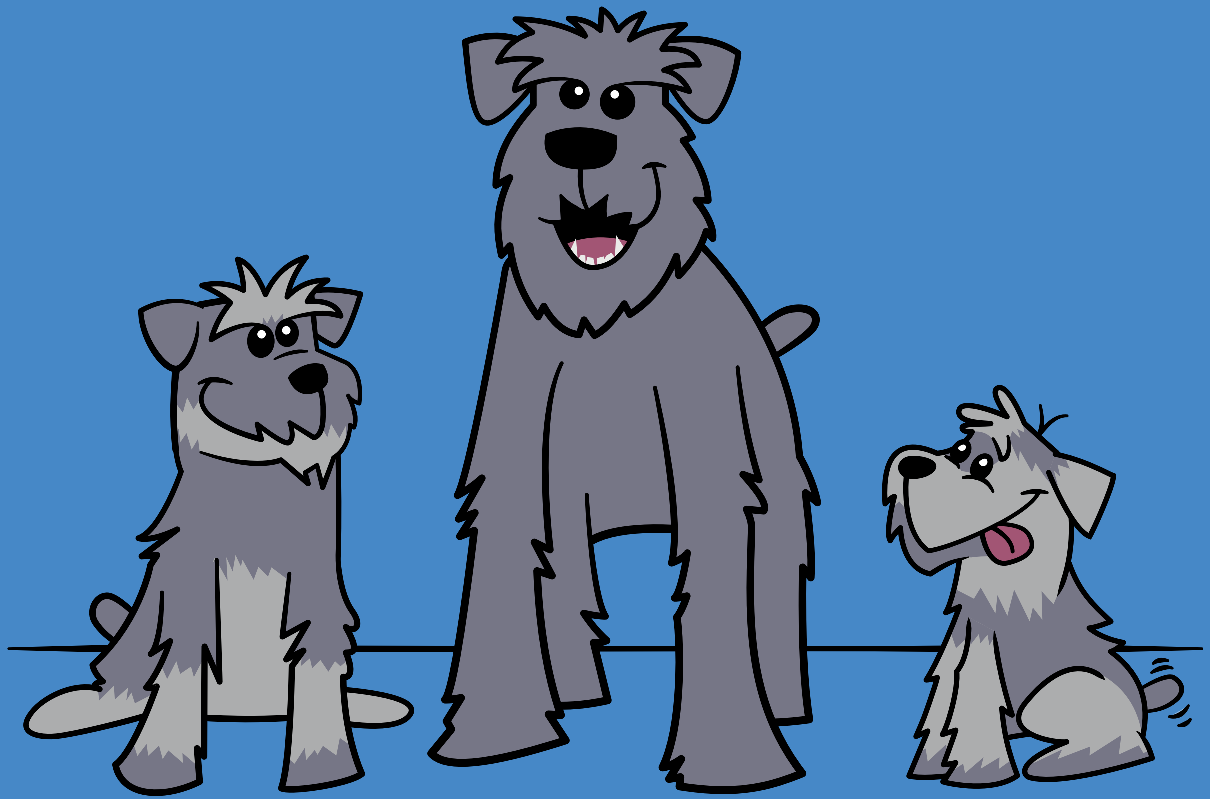
- How to define a class.
- How to create an object—that is, an instance of a class.
- How to add properties to a class, and how to access them.
- How to add functions to a class, and how to call them.
- How to create a UML diagram for a single class.
- How to call functions and get properties from the built-in Kotlin types that we've already worked with, such as `Double`, `String`, and `Boolean`.
- How to create single-instance objects.
- How to group code into packages.
- How to import code elements from other packages.

Now that we've covered the basics of classes, it's time to explore a special kind of class in Kotlin: an *enum class*. In the next chapter, we'll see how enum classes can be used to limit our options—and why that's a good thing!

Kotlin: An Illustrated Guide

Chapter 5

# Enum Classes



## Sometimes limiting your options is a good thing.

In the last chapter, we created our very own type, called `Circle`, using a feature in Kotlin called a *class*.

In this chapter, we're going to look at a special kind of class—an enum class—which is particularly useful when we want to represent a *limited number* of values.

I hope you like Schnauzers, because this chapter is full of them!

Schnauzers are amazing dogs—they're smart, they're loyal to their owners, and they seem to have an opinion about everything!

Let's create a **`String`** variable to hold the name of a pet Schnauzer.

```
val nameOfSchnauzer: String = "Shadow"
```

*Listing 5.1 - Creating a variable to hold the name of a Schnauzer.*

How many different names for Schnauzers can you think of? *Shadow*, *Rover*, and *Captain Fluffybeard* come to mind, but there's really no limit to the variety of names that could be given to them. The possibilities are *unlimited!*

Schnauzer *breeds*, however, are a different story! There are only 3 breeds of Schnauzer.

1. Miniature Schnauzer
2. Standard Schnauzer
3. Giant Schnauzer

So, while the number of *names* for a Schnauzer is *unlimited*, the number of *breeds* is *limited* to just 3 options.

How does all of this relate to programming?

Well, when we're writing code, we can reduce the likelihood of errors by choosing a type that *limits* the range of possible values to only those that are valid.

For example, a **`String`** can hold practically any text you can imagine. Since you can name your dog almost anything imaginable, it would make sense to use a **`String`** to hold its name.

On the other hand, a **`String`** would *not* be a great choice to hold the specific *breed* of a Schnauzer. Why? Because strings can hold an infinite number of different values, but there are only 3 possibilities that could be correct for a Schnauzer breed. In other words, when using a **`String`**, there's no way to guarantee that we will set a breed variable to one of those three correct values.

To demonstrate this, let's say we decided to use a **`String`** to represent the breed, like this.

```
val breedOfSchnauzer: String = "Miniature"
```

*Listing 5.2 - Creating a variable to hold the breed of a Schnauzer.*

Now, somewhere else in our code, we might have a conditional that's checking the breed.

```
if (breedOfSchnauzer == "Mini") {
    // ... do something
}
```

*Listing 5.3 - A conditional that expected a slightly different breed name than we used above.*

We might have intended that the conditional expression would evaluate to `true`, but since we incorrectly typed `"Mini"` instead of `"Miniature"`, it would have evaluated to `false`… and we wouldn't have known that anything was wrong until we ran the code!

The problem is that we used a type that allows *unlimited* values (that is, the `String` type), when we needed a type that allows only a *limited* number of values. If we could create a type that only allows one of the three breed names, the error above wouldn't even be possible!

To create a type with *limited* values in Kotlin, we use an *enumeration class*, or as we more often refer to it, an **enum class**, or just an **enum**.

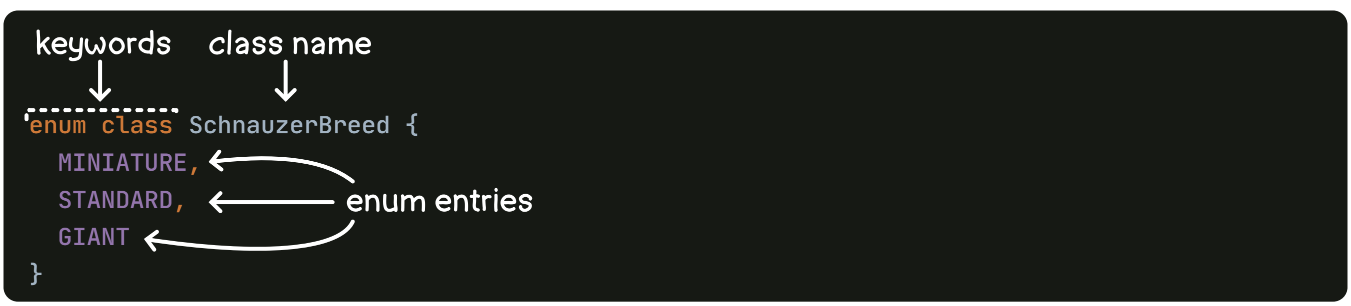
# Creating an Enum Class

Let's create an enum class to represent Schnauzer breeds.

```
enum class SchnauzerBreed {
    MINIATURE,
    STANDARD,
    GIANT
}
```

*Listing 5.4 - Creating an enum class with three options.*

This enum class is named `SchnauzerBreed`, and it gives us three breed options to choose from. Here are the main parts of an `enum class`.




1. To create an enum class, we write `enum class` rather than just `class`.

2. After that comes the name that we want to give our class—in this case, `SchnauzerBreed`.

3. Inside the body of the class, the *options* are called **enum entries**. Sometimes we call them **enum constants** instead. They're separated with commas, and by convention, they're written in all capital letters.

# Using an Enum Class

Now that we have an enum class, we can start using it. Note that we will not construct an object from an enum class in the same way that we would do with normal classes. If we try, we'll get an error.

```
val breed: SchnauzerBreed = SchnauzerBreed()
```

*Listing 5.5 - **Error:** "Cannot access '<init>': it is private in 'SchnauzerBreed' / Enum types cannot be instantiated" (does not compile).*

Instead, we just assign a variable to one of the entries, like this.

```
val breed: SchnauzerBreed = SchnauzerBreed.GIANT
```

*Listing 5.6 - Assigning a variable to one of the enum options.*

By using an enum class here, if we were to accidentally type `MINI` instead of `MINIATURE`, then Kotlin would give us an error immediately—before we even run the code!

```
val breed: SchnauzerBreed = SchnauzerBreed.MINI
```

*Listing 5.7 - **Error:** "Unresolved reference: MINI" (does not compile).*

So instead of using a `String`, which can be set to just about *anything*, we limited the valid options to just *three* enum entries. By doing that, Kotlin can now help tell us when we typed something wrong, without having to even run the code!

# Using Enum Classes with `when` Expressions

Another nice benefit of using enum classes is that Kotlin provides some added assistance when we use them with a when expression.

As you might recall, `when` expressions must account for every condition—that is, they must be exhaustive. Because enum classes limit the possible values, Kotlin can use this information to know when we have indeed accounted for every condition.

For example, here's some code that returns a description of a breed.

```
fun describe(breed: SchnauzerBreed) = when (breed) {
    SchnauzerBreed.MINIATURE -> "Small"
    SchnauzerBreed.STANDARD  -> "Medium"
    SchnauzerBreed.GIANT     -> "Large"
}
```

*Listing 5.8 - Using an enum class with a `when` expression.*

Notice that there's no `else` condition here! Kotlin can tell that we've included *all three* of the enum entries in the `when` body, so there are no other possibilities.

If we were to omit some of the entries, Kotlin would give us an error.

```
fun describe(breed: SchnauzerBreed) = when (breed) {
    SchnauzerBreed.MINIATURE -> "Small"
    SchnauzerBreed.STANDARD  -> "Medium"
}
```

*Listing 5.9 - **Error:** "'when' expression must be exhaustive" (does not compile).*

To remedy this error, we would either have to provide *all* of the enum constants, as we did in Listing 5.8, or we'd have to provide an `else` condition, like this.

```
fun describe(breed: SchnauzerBreed) = when (breed) {
    SchnauzerBreed.MINIATURE -> "Small"
    SchnauzerBreed.STANDARD  -> "Medium"
    else                     -> "Unknown"
}
```

*Listing 5.10 - Providing an `else` branch, because not all of the enum entries are represented in the `when` expression.*

It's great that Kotlin will give us an error when our `when` is not exhaustive. For example, whenever we add a new entry to an existing enum class, Kotlin will give us errors in *all* of the `when` expressions that need to be updated—so we can know exactly what parts of our code need to be fixed!

# Adding Properties and Functions to Enum Classes

As you recall from the last chapter, normal Kotlin classes allow us to put [properties and functions together](). Well, it's also possible to add properties and functions to an enum class.

Let's start by adding a property as a [constructor parameter](). We can do this just as we did with normal classes—by putting them between the opening `(` and closing `)` parentheses after the name of the class.

For example, we might want to include the approximate height of each breed, in centimeters. We can do that like this.

```
enum class SchnauzerBreed(val height: Int) {
    MINIATURE(33),
    STANDARD(47),
    GIANT(65)
}
```

*Listing 5.11 - Adding a constructor parameter to an enum class.*

Because we added a new *constructor parameter* called `height`, we also had to add a *constructor argument* to each of the enum entries. So a miniature has an approximate height of 33 cm, a standard is about 47 cm, and a giant is about 65 cm tall.

Note that the enum entries are in fact instances of the enum class.

We can get a property off of an enum instance just like we would do with regular objects. For example, we can print the height of a breed to the screen with **`println()`**.

constructor parameter

```
enum class SchnauzerBreed(val height: Int) {
  MINIATURE(33),
  STANDARD(47),
  GIANT(65)
}
```

constructor arguments

```
println(SchnauzerBreed.MINIATURE.height)
```

*Listing 5.12 - Getting a property of an enum class.*

We can also include a property that does not require a constructor argument. Let's add a property that tells us the **`family`** of breeds that they all belong to.

```
enum class SchnauzerBreed(val height: Int) {
    MINIATURE(33),
    STANDARD(47),
    GIANT(65);

    val family: String = "Schnauzer"
}
```

*Listing 5.13 - Adding a property to an enum class, without making it a constructor parameter.*

The new **`family`** property is added to the end of the class body. Notice the semicolon after the last entry!

## By the Way: Semicolons

In many programming languages, a semicolon is required after each statement. In Kotlin, as long as a statement is on its own line of code, everything works just fine. So, there aren't many times in Kotlin when we have to use a semicolon, but this is one of them.

It's just as easy to add a function. As above, be sure to include the semicolon, and then simply write the function beneath the enum entries.

```
enum class SchnauzerBreed(val height: Int) {
    MINIATURE(33),
    STANDARD(47),
    GIANT(65);

    val family: String = "Schnauzer"

    fun isShorterThan(centimeters: Int) = height < centimeters
}
```

*Listing 5.14 - Adding a function to an enum class.*

When *using* an enum class, we can get properties and call functions just as we would with any other class.

```
println(SchnauzerBreed.STANDARD.family)
println(SchnauzerBreed.STANDARD.isShorterThan(40))
```

*Listing 5.15 - Using a property and function from an enum class.*

# Built-In Properties

In addition to any properties that you include yourself, Kotlin also automatically adds a couple of properties to *all* enum instances. Before we wrap up this chapter, let's take a look at those.

## `ordinal`

Each enum entry has a property named **`ordinal`**, which tells us its position—*where this enum entry appears in the list*. The first entry in the list has an ordinal of 0, the second has an ordinal of 1, the third has an ordinal of 2, and so on. For example, since **`STANDARD`** is the second entry in the list, it has an ordinal of 1.

Yes, it starts with zero, which can be a bit confusing for those who haven't done much programming before. Once we get to the topic of *collections* in Chapter 8, we'll see how *zero-based* numbering is used a lot in programming!

```
   enum class SchnauzerBreed(val height: Int) {
0 → MINIATURE(33),
1 → STANDARD(47),
2 → GIANT(65)
   }
```

## `name`

When we need to know the name of the enum entry as a string, we can use the **`name`** property. To demonstrate this, let's create a function that tells us the **`name`** of the breed, along with the **`height`**.

```
fun describe(breed: SchnauzerBreed) {
    println(breed.name)
    println(breed.height)
}
```

*Listing 5.16 - Using the **`name`** property that Kotlin automatically includes in all enum classes.*

Now, we can call **`describe(SchnauzerBreed.STANDARD)`**, and we'll see this on the screen.

```
STANDARD
47
```

## Technically Speaking: Getting an Entry from a String

The **`name`** property can be used to get a **`String`** from a **`SchnauzerBreed`**. In some cases, though, we might want to go the other way—to get the **`SchnauzerBreed`** from a **`String`**.

To do this, Kotlin automatically includes a function called **`valueOf()`** on the enum class. Here's an example showing how we can use it.

```
val nameOfBreed = "STANDARD"
val breed = SchnauzerBreed.valueOf(nameOfBreed)

println(breed.height) // Prints "47"
```

When this code runs, if we were to call **`valueOf()`** with a string that doesn't match any entries, we'd get an error.

There's more than this! We can also get all of the **`entries`** out of an enum class. However, this won't be helpful until we learn how to iterate over values, which we'll cover in Chapter 8. For now, let's wrap up this chapter!

# Summary

Here's what we learned in this chapter:

- How limiting the range of values can help make sure our programs are written correctly.
- How to create an enum class.
- How to use enum classes with the "when" conditional.
- How to add properties and functions to an enum class.
- How to use some built-in properties of enum classes.

At this point, we've created lots of variables, each one holding a value. But what about when we need to handle the *absence* of a value? In the next chapter, we'll learn about *nulls* and the tools that Kotlin provides to handle them safely!

# Nulls and Null Safety

## What can you do when there's nothing in that variable?

So far in this book, every time that we created a variable, whether it was a **`String`**, an **`Int`**, or a **`Boolean`**, we assigned a *value* to it. There are times, though, when we need to create a variable that might *not* actually hold a value!

This brings us to the exciting topic of *nulls!*

# Introduction to Nulls

James has set up a coffee stand downtown, and he's ready to start sharing his fine brew! After handing out each cup, he asks the guest to review the coffee, so that he can share the ratings with others who might be interested, hoping that it will encourage others to try his coffee. To the right is an example of the review form that he provides to his guests.

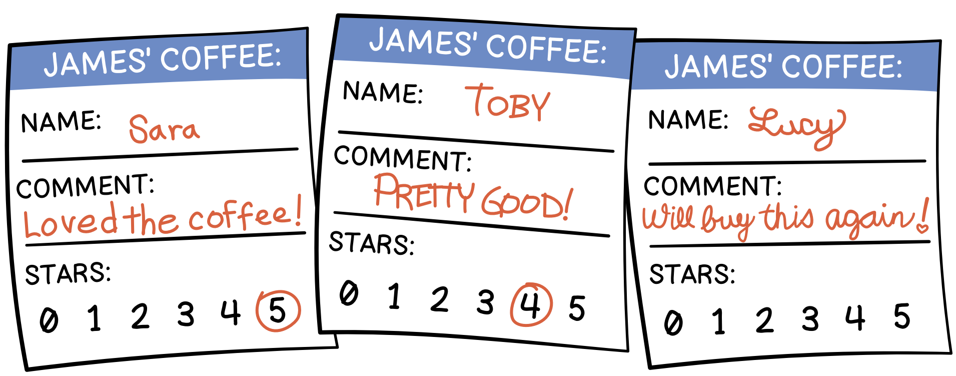

Since he wanted to keep track of the ratings in a Kotlin program, he wrote this simple class.

```
class CoffeeReview(
    val name: String,
    val comment: String,
    val stars: Int
)
```

*Listing 6.1 - A simple class that represents what someone thought about James' coffee.*

The **name** property represents the name of the person who is reviewing his coffee, the **comment** property is used for any comment that they want to share about it, and the **stars** property holds the star rating—the number of stars that they give the coffee, between 0 and 5.

The first three guests of the day have filled out the review cards. Here's how they rated his coffee!




James instantiated some **CoffeeReview** objects to record the three reviews that he received. He started with the first two.

```
val saraReview = CoffeeReview("Sara", "Loved the coffee!", 5)
val tobyReview = CoffeeReview("Toby", "Pretty good!", 4)
```

*Listing 6.2 - Instantiating a few **CoffeeReview** objects.*

When he got to Lucy's review, though, he noticed that she forgot to leave a star rating. "That's okay," he said to himself, "I'll just use the number zero since she didn't mark any stars."

```
val lucyReview = CoffeeReview("Lucy", "Will buy this again!", 0)
```

*Listing 6.3 - Using a star rating of 0 because Lucy forgot to mark a star rating on the review card.*

He was ready to show the reviews on a screen, so he wrote a simple function, and called it with each of the reviews that he received.

```
fun printReview(review: CoffeeReview) =
    println("${review.name} gave it ${review.stars} stars!")

println("Latest coffee reviews")
println("---------------------")
printReview(saraReview)
printReview(tobyReview)
printReview(lucyReview)
```

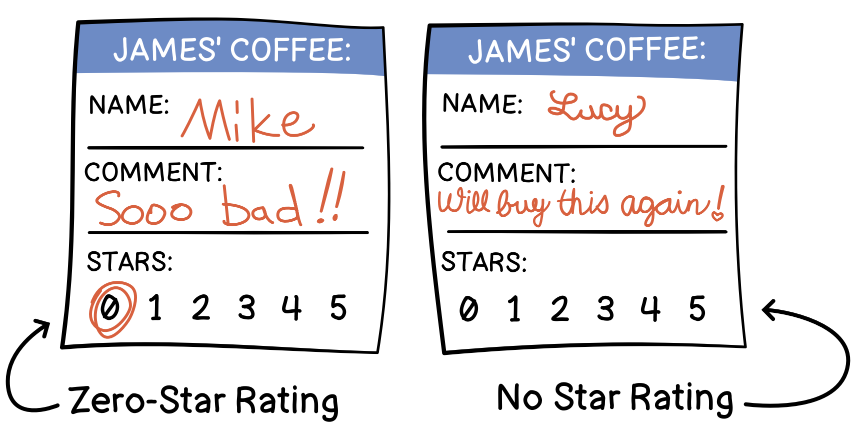
*Listing 6.4 - Printing the coffee reviews to the screen.*

This is what showed on the screen.

```
Latest coffee reviews
---------------------
Sara gave it 5 stars!
Toby gave it 4 stars!
Lucy gave it 0 stars!
```

He thought that his solution would work well, but when the guests saw the review, they thought, "Wow, if Lucy didn't like the coffee, maybe it's not good. I'll go somewhere else."

James realized that a *zero-star rating* is not the same thing as having *no star rating*.




When someone doesn't leave a star rating, then James doesn't want to show a zero-star rating on the screen. Instead, he needs a way to tell Kotlin that the guest didn't leave a star rating at all. How can he do that?

## Present and Absent Values

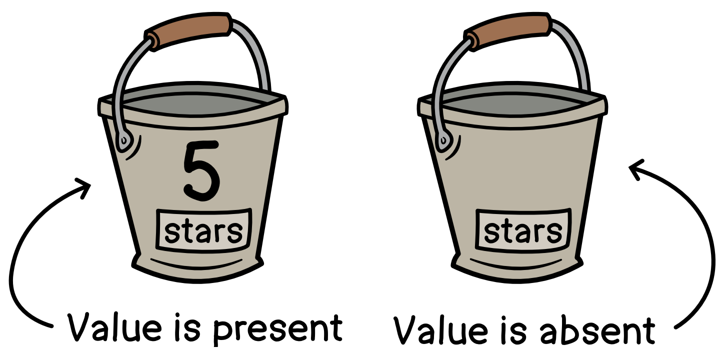

As you might recall from Chapter 1, a variable is like a bucket that holds a value.

In all the code that we've written so far, we've created variables that *contain a value*. In other words, we've always had something *inside* that bucket. For example, a **`stars`** bucket contains an **`Int`**, like the number 5.

For the **`CoffeeReview`** class, we need a **`stars`** bucket that *might or might not* have a value in it. When the guest leaves a rating, the bucket needs to contain that value, but when the guest forgets to rate it, that bucket needs to be empty.

So we want a bucket where we can either put a value inside of it, or leave it empty. This brings up two new terms:

- When a variable has a value inside of it, we'll say that the value is **present**.
- When a variable does not have a value inside of it, we'll say that the value is **absent**.




Kotlin uses the keyword **`null`** to represent the absence of a value.[1] A variable that is assigned **`null`** is like a bucket that's empty.[2]

When a review omits the star rating, we want to set **`stars`** to **`null`**. We can try giving it a **`null`** when we construct Lucy's **`CoffeeReview`**, but when we do that, we get an error.

```
val lucyReview = CoffeeReview("Lucy", "Will buy this again!", null)
```

*Listing 6.5 - **Error:** "Null can not be a value of non-null type Int" (does not compile).*

In fact, even apart from the **`CoffeeReview`** class, if we simply create an **`Int`** variable called **`stars`**, we can't assign **`null`** to it.

```
val stars: Int = null
```

*Listing 6.6 - **Error:** "Null can not be a value of non-null type Int" (does not compile).*

[1] In some Latin-based languages, the word "null" is more closely related to the number zero, but in English it more often refers to something that has no value or effect. When you see it in Kotlin, don't think of it as the number zero; think of it as "not having a value".

[2] Technically, even **`null`** can be considered a value. So, you might hear someone say, "The value of that variable is null," and that's fine. However, since the concepts of "present" and "absent" are more intuitive, in this chapter, we'll regard **`null`** as the absence of a value rather than as a value itself.

Why is this? Well, in some programming languages, it's possible to assign a **`null`** to *any* variable. That might sound like a good idea, but it can result in lots of surprises while the code is running, because we never have any guarantees that the value of a variable is present.

In order to help prevent these kinds of problems, Kotlin won't let us assign **`null`** to just *any* variable. Instead, we have to *clearly indicate* when a variable can be empty. How can we do this?

## Nullable and Non-Nullable Types

In Kotlin, we use different types to indicate whether a variable can or cannot be set to **`null`**.

All of the types that we've used so far—such as **`String`**, **`Int`**, and **`Boolean`**—*require* us to assign an actual value. We can't just assign **`null`** to them, as we discovered above. Since they don't let us assign **`null`**, we call them **non-nullable types**. In contrast, types that allow us to assign **`null`** are called **nullable types**.

In other words:

- When you want to *guarantee* that a variable's value will be present—that is, when the value is **required**—then give the variable a *non-nullable* type.
- When you want to *allow* a variable's value to be absent—that is, when the value is **optional**—then give the variable a *nullable* type.

In Kotlin, nullable types end with a question mark. For example, while **`Int`** is a *non-nullable* type, **`Int?`** (ending with a question mark) is a *nullable* type.

For every non-nullable type, a corresponding nullable type exists.

| NON-NULLABLE | NULLABLE TYPES |
| --- | --- |
| String | String? |
| Int | Int? |
| Boolean | Boolean? |
| Circle | Circle? |
| SchnauzerBreed | SchnauzerBreed? |

Let's look at our code from Listing 6.6 again.

```
val stars: Int = null
```

*Listing 6.7 - **Error:** "Null can not be a value of non-null type Int" (does not compile).*

To allow this variable to accept **`null`**, we simply change **`stars`** from the non-nullable type **`Int`** to the nullable type **`Int?`**, like this.

```
val stars: Int? = null
```

*Listing 6.8 - Notice the question mark at the end of* **`Int`**.

Now, **`stars`** can be set to **`null`**. Of course, it can also still be set to a normal integer value.

```
val saraStars: Int? = 5
val tobyStars: Int? = 4
val lucyStars: Int? = null
```

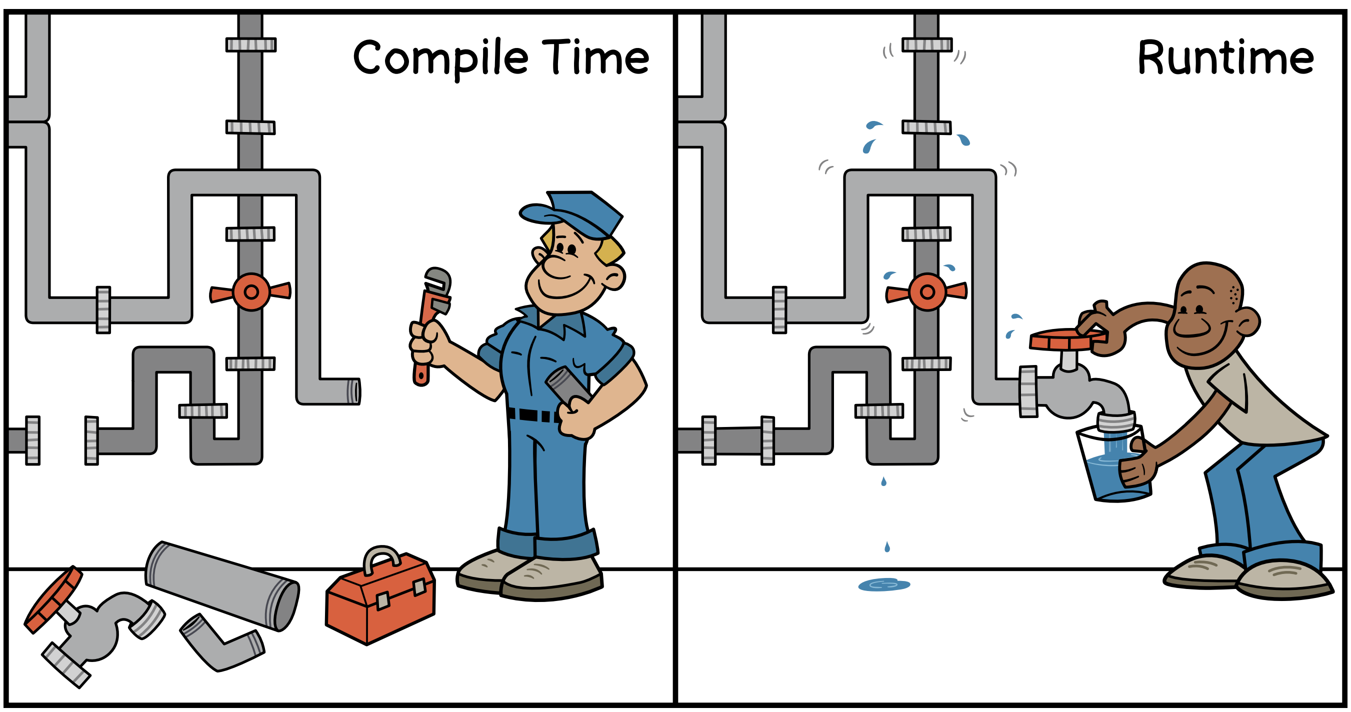
*Listing 6.9 - Setting nullable variables to either non-null values or null.*

# Compile Time and Runtime

The type of a variable tells us whether that variable *can* hold a null, but it cannot tell us whether it actually *does* hold a null. This brings up an important distinction to consider. There are things we can know when Kotlin is *reading* the code, and there are things we can know when we're *running* the code.

- The point at which *Kotlin is reading our code* is called **compile time**. If we're using an IDE like IntelliJ or Android Studio, this happens while we are *writing the code*.
- The point at which our computer *runs our Kotlin code* is called **runtime**.

The plumber needs to *assemble* the water pipes before we can turn on the faucet. That's a lot like *compile time*—Kotlin is busy assembling our code into something that can be used. Once the pipes are fully assembled, we can turn on the faucet to get a drink of water. That's what *runtime* is—Kotlin has finished assembling the code, and now we're finally using it.




Kotlin knows the type of a variable at *compile time*, which is why it knows whether it can hold a null while we're writing the code. On the other hand, Kotlin won't know whether a variable *actually* holds a null until runtime.

In some simple cases like Listing 6.9, where we're setting the variable with a literal directly in the code, it seems obvious to us whether the value is present or absent. In fact, your IDE might even warn you when you use a non-null value with a variable that's declared to be nullable—like **saraStars** and **tobyStars** above.

But it's not always so obvious. Values can also come from *external* sources, like databases, files on a hard drive, or a keyboard that a user is typing on—and those values could be **null**. Similarly, when calling a function that has a nullable parameter, it's possible that the argument is **null** at one call site, but present at another.

In order to check whether a variable *actually* has a value at runtime, we have to try converting it from a nullable type to a non-nullable type. We'll see some cool tricks for this in a moment. But first, it's important to understand the relationship between nullable and non-nullable types.

# How Nullable and Non-Nullable Types are Related

Even though **Int** and **Int?** are related, they're still two different types, and we can't just use an **Int?** anywhere that we would use an **Int**. For example, a function that expects an **Int** won't work if we try to send it an **Int?** instead.

```
fun printReview(name: String, stars: Int) =
    println("$name gave it $stars stars!")

val saraStars: Int? = 5

printReview("Sara", saraStars)
```

*Listing 6.10 - **Error:** "Type mismatch. Required Int / Found Int?" (does not compile).*

Why is this so? To understand this, let's turn our attention away from the review screen, and toward the front counter, where James is taking the coffee orders!

## Expecting a Nullable Type

At the moment, James is running a non-profit coffee *charity*, which provides warm beverages to anyone, even if they can't pay for it. If the guest would like to donate a payment, they can, but it's not required.

Here's a function that models this arrangement. The payment at a charity is *optional*, so we'll make the payment parameter *nullable*.

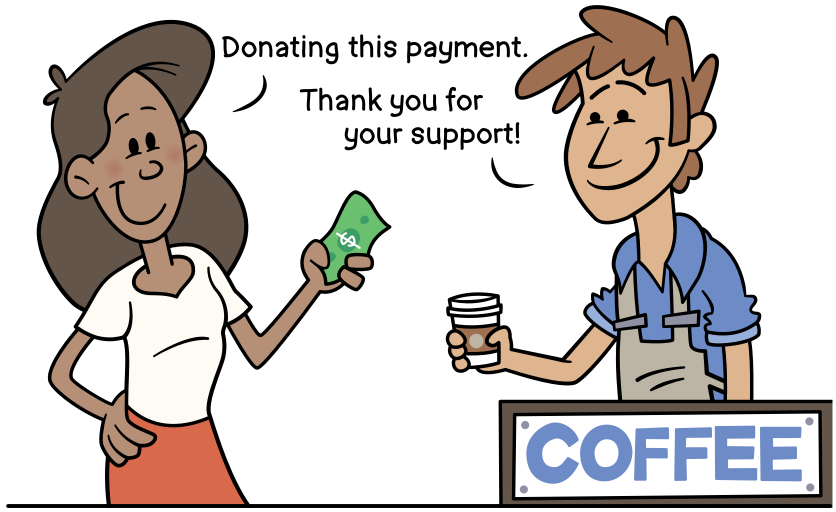
```
fun orderCoffee(payment: Payment?): Coffee {
    return Coffee()
}
```

*Listing 6.11 - A function for ordering coffee where payment is optional, such as for a charity.*

Naturally, if someone orders a coffee and provides payment, James will gladly hand over a coffee.

The payment isn't required, but he appreciates the support!

Passing a `Payment` argument to the `orderCoffee()` function, as shown in Listing 6.12 below, is like this scenario—the guest is definitely providing payment.



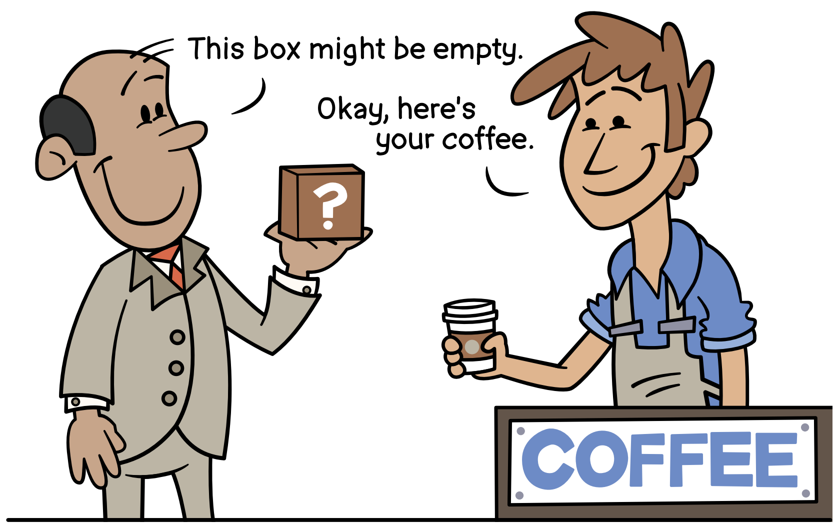

```
val payment: Payment = Payment()
val coffee = orderCoffee(payment)
```

*Listing 6.12 - Providing payment for a coffee at the coffee charity.*

Now, imagine that someone walks in and says, "This box *might* have a payment… or it *might* be empty. You can have whatever is inside."

James says, "Even if it's empty, that's fine. We're a charity, after all. Here's your coffee!"

When we pass a `Payment?` argument to the `orderCoffee()` function, it's like the guest is handing James a mystery box that contains either a payment or nothing at all.

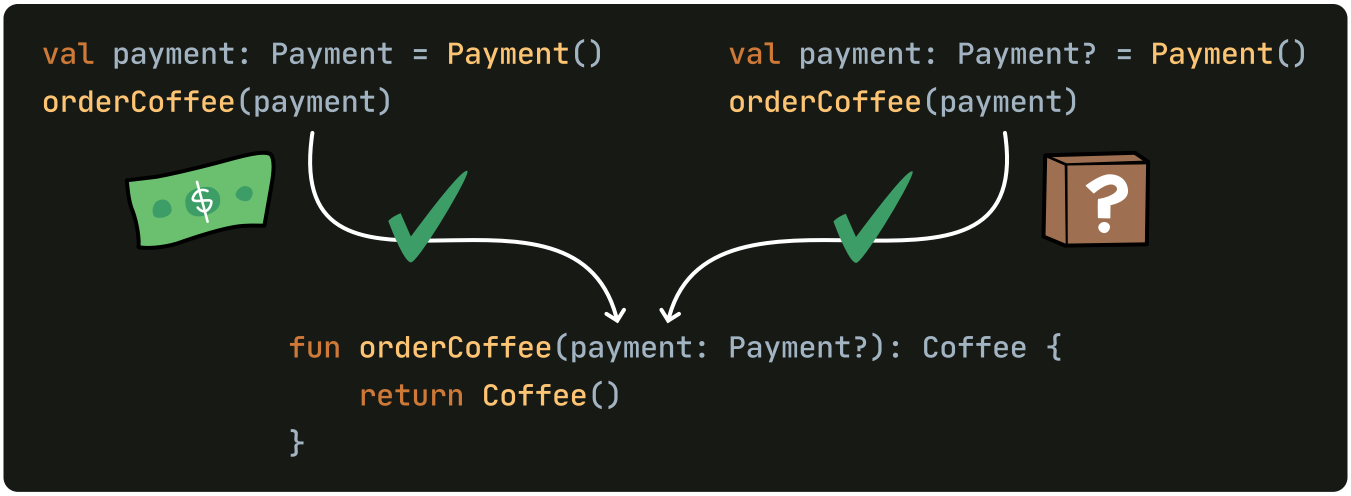



```
val payment: Payment? = Payment() // or set this to null
val coffee = orderCoffee(payment)
```

*Listing 6.13 - Maybe providing a payment for coffee… or maybe not!*

To summarize, a function that has a nullable parameter like `Payment?` is like a charity.

- It can accept an argument that has a *non-nullable* type, like `Payment`.
- And it can also accept an argument that has a *nullable* type, like `Payment?`.




## Expecting a Non-Nullable Type

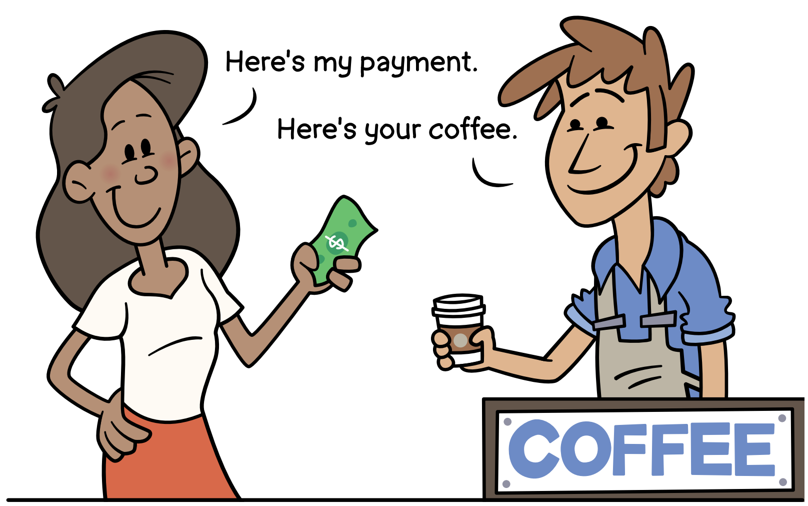
After a while, James realized that he couldn't get enough donations to sustain the charity, so now he's running his coffee stand as a *business*. All those coffee beans cost money, and since the business doesn't run from donations, he *must* receive *payment* in order to provide coffee to the customer.

Here's a new version of **`orderCoffee()`** that works like a business rather than a charity. Notice that the parameter has a non-nullable type, because **`payment`** is now required.

```kotlin
fun orderCoffee(payment: Payment): Coffee {
    return Coffee()
}
```

*Listing 6.14 - A function for ordering coffee where payment is required, such as for a business.*

As before, when someone orders a coffee and provides payment, James will gladly hand over a coffee.



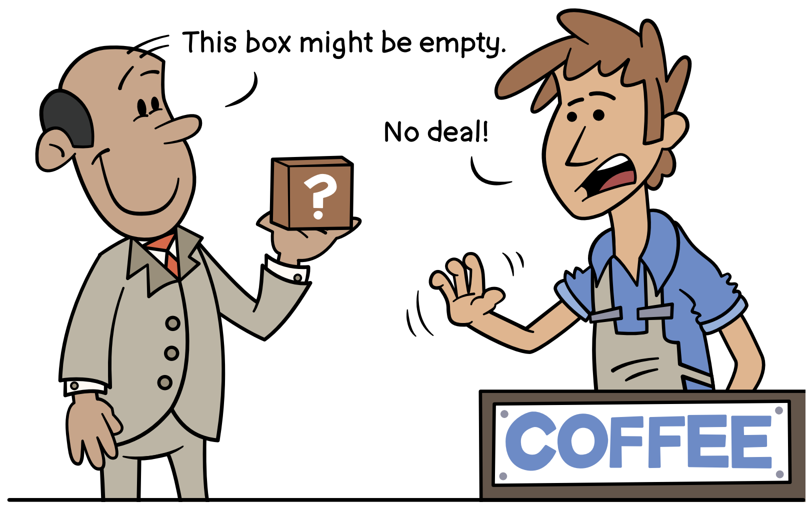

Passing a **`Payment`** variable to this function is much like this scenario—the guest is definitely providing payment, so everything works just fine, as demonstrated in Listing 6.15 below.

```kotlin
val payment: Payment = Payment()
val coffee = orderCoffee(payment)
```

*Listing 6.15 - Providing payment for a coffee at the coffee business.*

Now imagine that someone orders a coffee, but instead of giving payment, holds out a box, and says, "This box *might* have a payment… or it *might* be empty. I'll trade you whatever is inside this box for a coffee."

"No deal!" James says. "You have to actually *pay* for your coffee! I can't trade the coffee for a *chance* to receive payment. I have to actually *receive* payment!"

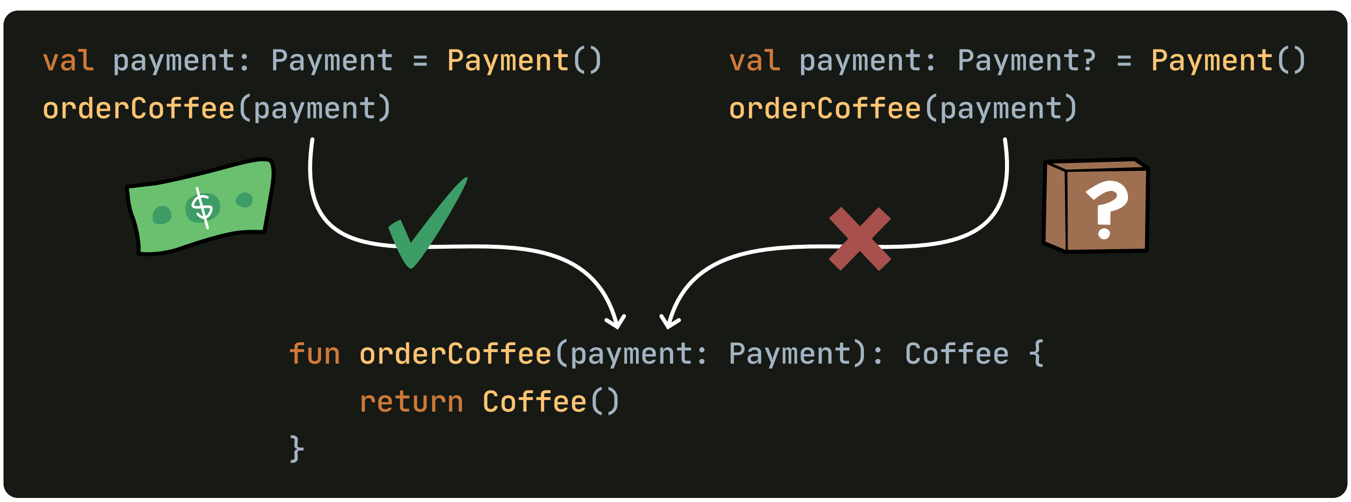



Passing a **`Payment?`** variable to this function is like this scenario—the guest is either handing James a payment or nothing at all. Just like James, Kotlin says, "No deal!" (…well, actually it says, "Type mismatch.")

```
val payment: Payment? = Payment() // or you could set this to null
val coffee = orderCoffee(payment)
```

*Listing 6.16 - **Error:** "Type mismatch. Required Payment / Found Payment?" (does not compile).*

When James *requires* payment, he can't accept a payment that *might not* be there. It must be there. So a function that has a parameter of type **`Payment`** is like a business—it cannot accept an argument of type **`Payment?`**.




To summarize, we can use a non-nullable type (e.g., **`Payment`**) where a nullable type (e.g., **`Payment?`**) is expected, but not the other way around.

Now, it's quite possible that the customer's box *actually* has a payment inside! If only they would take the payment out of the box, then they could exchange that payment for coffee! Similarly, Kotlin gives us a few different ways to *safely* convert a nullable type to a non-nullable type. Let's take a look!

# Using Conditionals to Check for `null`

Here again is the function for the coffee shop business.

```
fun orderCoffee(payment: Payment): Coffee {
    return Coffee()
}
```

*Listing 6.17 - An* **`orderCoffee()`** *function for the coffee business.*

When the customer tried to pay with a box that might be empty, it looked like this.

```
val payment: Payment? = Payment()
val coffee = orderCoffee(payment)
```

*Listing 6.18 -* ***Error:*** *"Type mismatch. Required Payment / Found Payment?" (does not compile).*

One simple way to order a coffee in this case is to check whether **`payment`** *actually* has a value at runtime. In other words, we can look inside the box, and if the payment is not **`null`**, then we can order the coffee.

```
val payment: Payment? = Payment()

if (payment != null) {
    val coffee = orderCoffee(payment)
} else {
    println("I can't order coffee today")
}
```

*Listing 6.19 - Using an* **`if`** *conditional to see whether payment is null.*

There's no error when we write this code, and **`orderCoffee()`** will be called when we run it. How does this work? Why can we call **`orderCoffee(payment)`** in Listing 6.19 but not Listing 6.18?

Even though we declared **`payment`** to be of type **`Payment?`** (which is nullable), inside the **`if`** block, its type changes to **`Payment`** (which is non-nullable)! Inside that block, Kotlin knows that **`payment`** must have a value, because we checked for it! This is called a **smart cast**.

```
val payment: Payment? = Payment()

if (payment != null) {
    val coffee = orderCoffee(payment)
} else {
    println("I can't order coffee today")
}
```

Type of `payment` is `Payment?` here (nullable)

Type of `payment` is `Payment` here (non-nullable)

Type of `payment` is back to `Payment?` again here

Smart casts also work with a `when` conditional, like this.

```
when (payment) {
    null -> println("I can't order coffee today")
    else -> orderCoffee(payment)
}
```

*Listing 6.20 - Smart cast using a* **when** *conditional.*

## By the Way: More Smart Casts

This isn't the only kind of smart cast that Kotlin can perform! We'll see them again in Chapter 12 when we learn about interfaces, subtypes, and supertypes.

So, using a conditional in this way is like opening the box, and if there's something inside it, we order the coffee.


Otherwise, if there's nothing inside the box, we don't order the coffee.

Using a conditional to do a smart cast is just one way to convert something that's nullable to something that's non-nullable! Next, let's look at the elvis operator.

### Technically Speaking: Smart Cast Limitations

In the code above, we used variables that were declared with the **`val`** keyword. If we try to do this kind of *smart cast* with a variable that's declared with the **`var`** keyword instead, in some cases it won't work!

As you might remember from Chapter 1, **`var`** makes it so that you can assign a new value to the variable, even after it's already been given one.

If a variable like this is defined *outside* of the function where you're trying to do the smart cast, there's a possibility that its value could change between the time you check to see if it's **`null`**, and the time when you're trying to use the variable inside the **`if`** block. This is especially a risk when multiple *threads* are running the code at the same time, which we'll see in Chapter 20. To prevent this problem, Kotlin will not do a smart cast in this case.

To work around this, create a new **`val`** variable inside your function, and assign it the value of your **`var`** variable. We'll see other workarounds for this in Chapter 11.

## Using the Elvis Operator to Provide a Default Value

In the code above, we *only* ordered coffee when a value was present in the **`payment`** variable. It sure would be nice if we could order a coffee even when we *don't* have payment. For example, if our **`payment`** variable is null, maybe our friend can pay for us!

```kotlin
val payment: Payment? = null

if (payment != null) {
    val coffee = orderCoffee(payment)
} else {
    val coffee = orderCoffee(getPaymentFromFriend())
}
```

*Listing 6.21 - If we don't have payment (that is, if* **`payment`** *is null), we get it from a friend instead.*

This allows us to order coffee in either case. If **`payment`** actually has a value, we can use that. Otherwise, we call the **`getPaymentFromFriend()`** function, which returns a **`Payment`** value that we can use instead.

As we learned back in Chapter 3, instead of an `if` statement we can use an `if` expression, which pulls the **`coffee`** variable outside of the **`if`** and **`else`** blocks. Let's make that small change to our code, in order to make it more concise.

```
val payment: Payment? = null

val coffee = if (payment != null) {
    orderCoffee(payment)
} else {
    orderCoffee(getPaymentFromFriend())
}
```

*Listing 6.22 - Lifting the assignment of* **`coffee`** *outside of the* **`if`** *body. Compare to Listing 6.21.*

We're also calling **`orderCoffee()`** in both branches, so let's pull that out of the **`if`** and **`else`** blocks, as well.

```
val payment: Payment? = null

val coffee = orderCoffee(if (payment != null) payment else getPaymentFromFriend())
```

*Listing 6.23 - Lifting the call to* **`orderCoffee()`** *outside of the if body. Compare to Listing 6.22.*

The code highlighted in Listing 6.23 is pretty common when dealing with nullable types: check whether a value is present… if so use that value, otherwise use some default value. To make this common expression easier, Kotlin gives us the **elvis operator**, which is a question mark and a colon.[1] Here's how we can use the elvis operator to make our code more concise.

```
val payment: Payment? = null

val coffee = orderCoffee(payment ?: getPaymentFromFriend())
```

*Listing 6.24 - Replacing the* **`if`** *expression with an elvis expression.*

This code works the same as the code in Listings 6.21, 6.22, and 6.23—it's just shorter and easier to read. Using an elvis operator is like opening the box, and if there's something inside it, we use that.


[1] If you tip your head to the left and squint your eyes, it kind of looks like an emoticon of Elvis Presley's hair line above a pair of eyes.

Otherwise, if the box is empty, we get a value from somewhere else and use that instead.


## Using the Not-Null Assertion Operator to Insist that a Value is Present

This one is dangerous, but in some rare cases, it can be a helpful option.

When we know for sure that a nullable variable will *definitely* have a value when the code is running, then we can use the **not-null assertion operator**, which is two exclamation marks, to evaluate it to a non-nullable type.

Here's how it would look when ordering coffee.

```
val payment: Payment? = Payment()
val coffee = orderCoffee(payment!!)
```

*Listing 6.25 - Using the not-null assertion operator to force a conversion from a nullable type to a non-nullable type.*

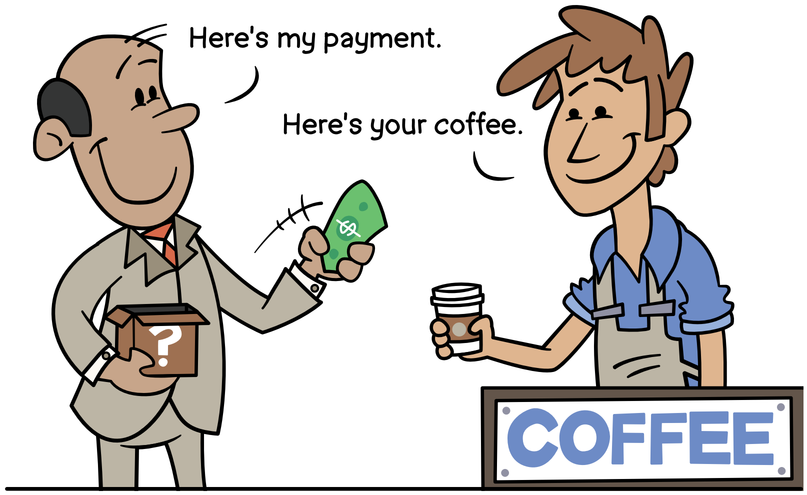
The type of the `payment` variable is `Payment?`, which is nullable, but the type of the expression `payment!!` is `Payment`, which is non-nullable.

By putting `!!` after the variable name `payment`, it's like you're saying to Kotlin, "Trust me… when the code runs, `payment` will not be null!" If you're wrong about that—if the variable is indeed null, you'll get an error when the code runs.

```
val payment: Payment? = null
val coffee = orderCoffee(payment!!) // ERROR AT RUNTIME!
```

*Listing 6.26 - You can run this code, but you'll get an error when you do!*

The not-null assertion operator is like reaching into the box, and if there's something inside, we use that…




Otherwise, if the box is empty…


This is why the not-null assertion operator is dangerous! In the other cases above—using a conditional to check for `null`, and using an elvis operator—it wasn't possible for us to get an error, because Kotlin's rules about nullable types wouldn't allow it. But here, we're foregoing that **null safety** and taking on risk that the variable might actually be `null` when the code is running.

## Compile-Time and Runtime Errors

We can get errors during either *compile time* or *runtime*.

- Listing 6.18 shows a *compile-time error*—the IDE highlights the problem while we're *writing* code.
- Listing 6.26 above shows code that will cause a *runtime error*, but unlike the compile-time error, there's no highlight to let us know that an error will happen. We only get the error while our code is *running*.

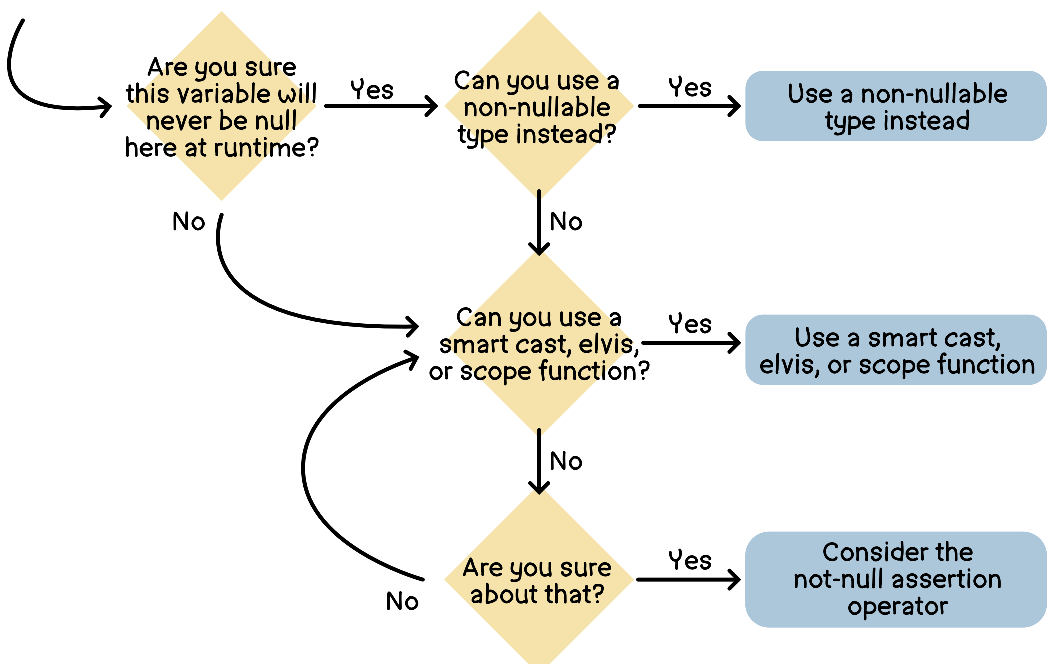
As a general rule, an error during compile time is more helpful than an error during runtime, because we know about it sooner. In fact, Kotlin won't even let us run our code until we've fixed it! Runtime errors, on the other hand, are nefarious and they're often more difficult to hunt down.

When we use the *not-null assertion operator* `!!`, we're avoiding a compile-time error, but taking a risk that we could end up with a runtime error.

If you're *certain* that the variable will not be null at runtime, then consider using a non-nullable type instead. If, for some reason, you can't do that, the not-null assertion operator might be what you need. But use it only as a last resort!

The flow chart below gives some advice about when to consider using non-nullable types, smart casts, not-null assertion operators, and so on. It also mentions *scope functions*, which we'll learn about in Chapter 11.

## When should I use the not-null assertion operator?




There's one more null-safety tool that Kotlin gives us. Let's check it out!

# Using the Safe-Call Operator to Invoke Functions and Properties

Back in Chapter 4, we saw how objects have functions and properties, and we can call those by using a dot operator. For example, let's say our `Payment` class has a property that tells us what type of payment the customer is using, whether cash, a check, or a card.

```
enum class PaymentType {
    CASH, CHECK, CARD;
}

class Payment(
    val type: PaymentType = PaymentType.CASH
)
```

*Listing 6.27 - Adding a* **`PaymentType`** *property to the* **`Payment`** *class.*

In this case, when we get a **`Payment`**, we probably want to do something with it, like print out the **`type`**. Let's update the **`orderCoffee()`** function to do that.

```
fun orderCoffee(payment: Payment): Coffee {
    val paymentType = payment.type.name.lowercase()
    println("Thank you for supporting us with your $paymentType")
    return Coffee()
}
```

*Listing 6.28 - Printing a message based on the type of payment used.*

This works great when the **`payment`** parameter is a non-nullable **`Payment`** type. But when its type is a nullable **`Payment?`** type—as it was when James was running the charity—then we get a compile-time error.

```
fun orderCoffee(payment: Payment?): Coffee {
    val paymentType = payment.type.name.lowercase()
    println("Thank you for supporting us with your $paymentType")
    return Coffee()
}
```

*Listing 6.29 - **Error:** "Only safe (?.) or non-null asserted (!!.) calls are allowed on a nullable receiver of type Payment?"*

Why is that?

Remember, a variable that has a nullable type—such as **`Payment?`**—is like a bucket that might be empty or might have a value… and we won't know whether it's empty until *runtime*. If the bucket is indeed empty while the code is running, then there would be no actual payment to get the **`type`** from.

In other words, if the **`payment`** isn't there, then neither is a payment **`type`**! It's not safe to get the type unless we know that the value of **`payment`** is present. Thankfully, Kotlin gives us a compile-time error, forcing us to deal with this fact.

In this chapter, we've already learned a few tricks that could help us. For example, we could use an **`if`** to do a *smart cast*.

```
fun orderCoffee(payment: Payment?): Coffee {
    val supportType = if (payment == null) {
        "encouragement"
    } else {
        payment.type.name.lowercase()
    }

    println("Thank you for supporting us with your $supportType")
    return Coffee()
}
```

*Listing 6.30 - Using an* `if` *conditional to provide a* `supportType` *when* `payment` *is null.*

When this code runs, if `payment` is null, we'll print "Thank you for supporting us with your encouragement". Otherwise, the message will be based on the `type` of payment, such as *"Thank you for supporting us with your cash"*.

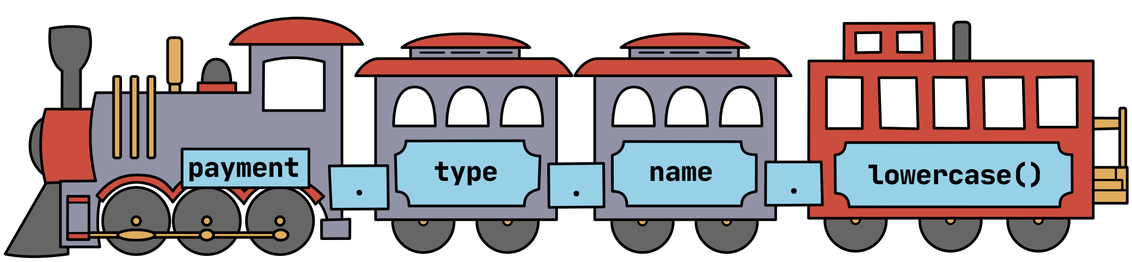
This certainly works, but it's a lot of code to write. Kotlin provides us with a **safe-call operator `?.`** that can do the same thing, just more concisely. We can use it along with the elvis operator to achieve the same thing as Listing 6.30, like this.

```
fun orderCoffee(payment: Payment?): Coffee {
    val supportType = payment?.type?.name?.lowercase() ?: "encouragement"
    println("Thank you for supporting us with your $supportType")
    return Coffee()
}
```

*Listing 6.31 - Using a safe-call operator and an elvis operator instead of an* `if` *conditional.*

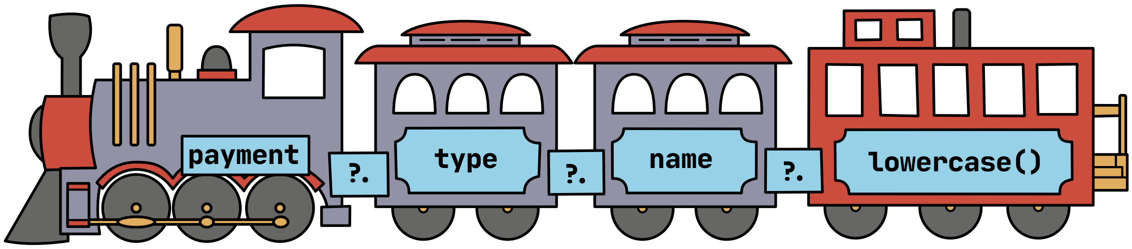
So, how does the safe-call operator work?

When we look at `payment.type.name.lowercase()`, it kind of looks like a train.[1]

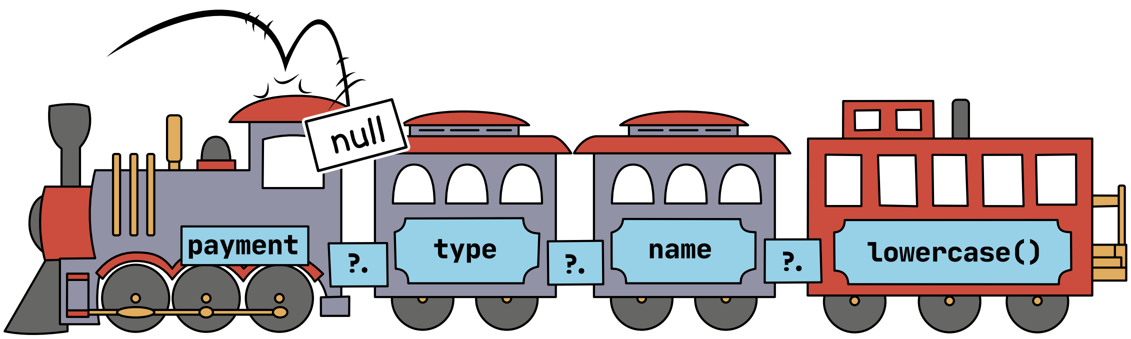



The main change in Listing 6.31 is that we replaced the train car *connectors*—where we previously used a dot, we now use a safe-call operator.

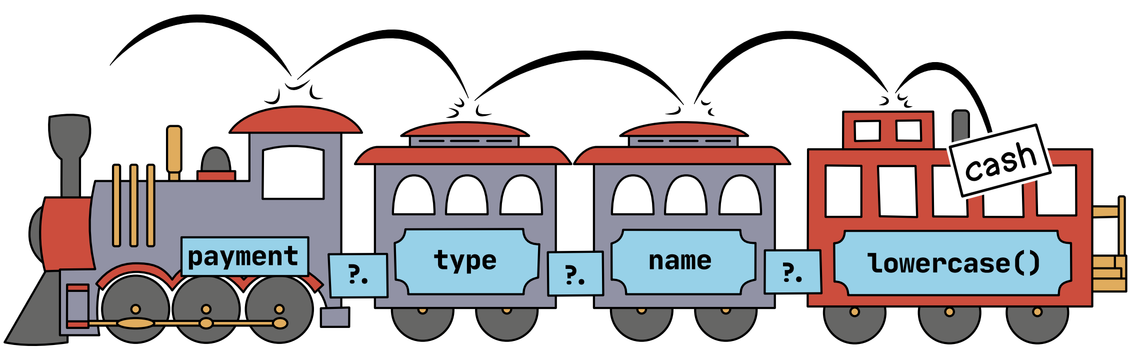
[1] In fact, the term "train wreck" has been used to describe expressions like this that have many function or property calls chained together. In this book, I won't add commentary about the advantages or disadvantages of expressions like these. So, instead of calling it a train wreck, I'll just call it a train!




When Kotlin evaluates a "train" expression like this, you can imagine that it's hopping from car to car, left to right. When the next connector is a safe-call operator, it asks, "Does this car's expression evaluate to null?" If so, then it hops off the train with a `null`.




Otherwise, it hops to the next car, repeating the process until it finds a null or jumps off the caboose with the final value.




Generally, when writing a train expression, if one of the cars has a nullable type, the *rest* of the train connectors *after* it will need to be safe-call operators rather than just dot operators. We'll see an exception to this when we get to *extension functions* in Chapter 10.

## Summary

James' coffee stand has come a long way! He learned that a zero-star rating isn't the same as having no star rating. He started off as a charity that *could* accept payment, and then brewed into a full-fledged business that *must* receive payment. And Kotlin's null-safety features helped him avoid some bitter surprises along the way! Here's what we covered in this chapter.

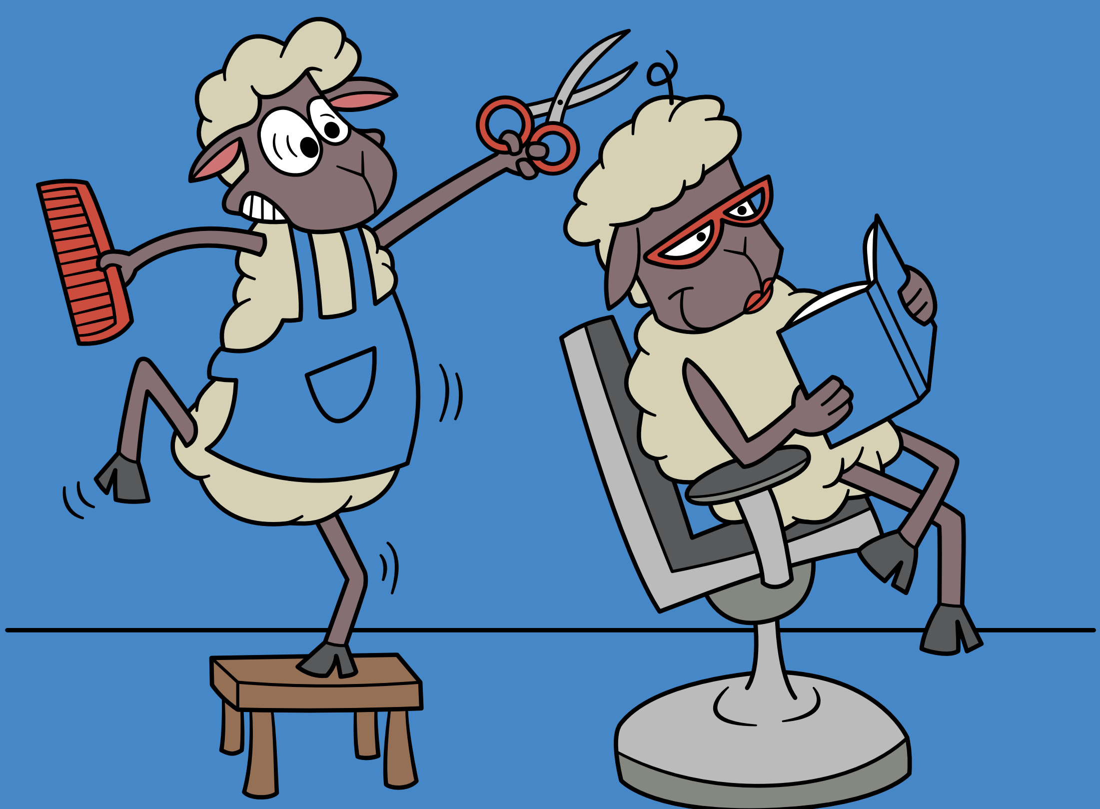
- The difference between present and absent values.
- The difference between non-nullable and nullable types.
- The difference between compile time and runtime.
- How to use conditionals to check for nulls.
- How to use the elvis operator to provide a default value.
- How to use the not-null assertion operator to insist that a value is present.
- How to use the safe-call operator to invoke functions and properties on a variable that's nullable.

Proper handling of nulls is an essential skill for every great Kotlin programmer. In the next chapter, we'll learn about another essential concept—lambdas!

Kotlin: An Illustrated Guide

Chapter 7

# Lambdas and Function References



## Hey! There’s a function in that variable!

As we’ve seen, functions are a basic building block of Kotlin code. Throughout this book, we’ve written a lot of them, all using the `fun` keyword. Kotlin also gives us another way to write functions - lambdas!

To help us learn about function types, function references, and lambdas, we’ll need to pay a visit to Bert’s Snips & Clips.

# Bert's Snips & Clips


*Bert's Snips & Clips* is the barber shop to go to for a clean haircut and a nice smooth shave. Although he prides himself on his low prices, sometimes he offers coupons that give the customer $5 off, to lower the price even further.

Once the customer has a fresh new haircut, he needs to calculate the *total cost*, so that he can charge the customer the right amount. Bert's pretty good at math, but to make this fast and easy, he created a simple Kotlin function to calculate the total.

His function needed to account for *tax* and the *five-dollars coupon*. Here's what he wrote.

```kotlin
// Tax is 9%, so we'll multiply by 109% to get the total with tax included.
val taxMultiplier = 1.09

fun calculateTotalWithFiveDollarDiscount(initialPrice: Double): Double {
    val priceAfterDiscount = initialPrice - 5.0
    val total = priceAfterDiscount * taxMultiplier

    return total
}
```

*Listing 7.1 - A simple function to calculate the total cost when using a coupon.*

If the customer has a $20 haircut and presents a $5 off coupon, he simply runs the function like this.

```kotlin
fun main() {
    val total = calculateTotalWithFiveDollarDiscount(20.0)
    println("$%.2f".format(total))
}
```

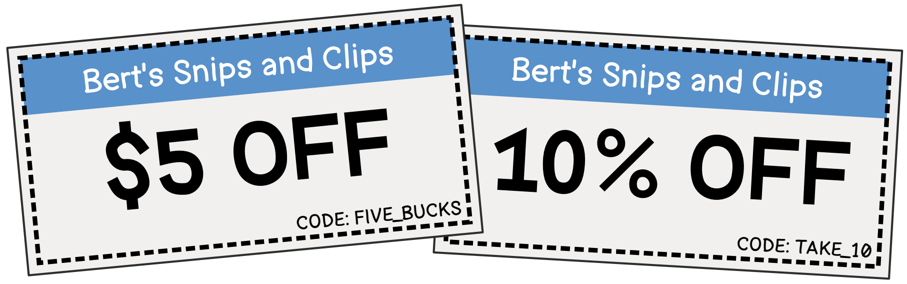
*Listing 7.2 - Calling the function from Listing 7.1.*

When he runs this code, it prints `$16.35`.

## Technically Speaking: String Formatting

What's with `"$%.2f".format()`? This tells Kotlin to print the number with a dollar sign on the left, and two decimal places to the right. Because of the multiplication, `total` could end up with more than two decimal places, so this will do rounding for us.

By the way, although we're using `Double` in these examples, you should consider using a type with greater precision (e.g., `BigDecimal`) in any *real* code that deals with money.




One day, one of Bert's customers spent a *lot* of money on haircuts for the whole family, and she was disappointed that she only had a *single* coupon for five dollars off.

In order to reward his most loyal, high-paying customers, he decided to introduce a 10% off coupon. That way, the more money they spend, the more dollars would be discounted.

Alongside the original function, Bert created a second function, which accommodates the new percent-based coupon. To calculate the price after a 10% discount, he just multiplies the initial price by 90%.

```
fun calculateTotalWithFiveDollarDiscount(initialPrice: Double): Double {
    val priceAfterDiscount = initialPrice - 5.0
    val total = priceAfterDiscount * taxMultiplier

    return total
}

fun calculateTotalWithTenPercentDiscount(initialPrice: Double): Double {
    val priceAfterDiscount = initialPrice * 0.9
    val total = priceAfterDiscount * taxMultiplier

    return total
}
```

*Listing 7.3 - One function for a $5 coupon, and one for a 10% coupon.*

When he looked at these functions, he realized that they're almost exactly the same, except for one small part—the part that *calculates the discounted price*.

```
fun calculateTotalWithFiveDollarDiscount(initialPrice: Double): Double {
    val priceAfterDiscount = initialPrice - 5.0
    val total = priceAfterDiscount * taxMultiplier

    return total
}

fun calculateTotalWithTenPercentDiscount(initialPrice: Double): Double {
    val priceAfterDiscount = initialPrice * 0.9
    val total = priceAfterDiscount * taxMultiplier

    return total
}
```

The only part that differs
(other than the name)

If only he could find a way to *pass code as an argument*… then he could consolidate his two functions down to one function that would look something like this.

```
fun calculateTotal(initialPrice: Double, applyDiscount: ???): Double {
    val priceAfterDiscount = applyDiscount(initialPrice)
    val total = priceAfterDiscount * taxMultiplier
    return total
}
```

*Listing 7.4 - Sketch of a function that might take a function as an argument. Doesn't actually compile.*

In other words, he just wants to tell **`calculateTotal()`** to apply a discount *in a different way* each time he calls it. If he could pass a function as an argument to **`calculateTotal()`**, that would solve his problem. But passing a function as an argument to another function? How could that be possible?

With Kotlin's *function types*, it's easy!

# Introduction to Function Types

Way back in Chapter 1, we saw how we could create variables that hold *values*. For example, to create a simple **`String`** variable that holds text, we can do this.

Variable

```
val name: String = "Bert"
```

Similarly, parameters are variables in a function where the calling code passes in their values when invoking the function.

Parameter

```
fun introduce(name: String) {
    println("My name is $name")
}

introduce("Bert")
```

So far, every time that we've assigned a variable or passed an argument to a function, we've been dealing with *values* of simple types like **`String`**, and **`Int`**, or even more complex objects of our own types, like **`Circle`**.

In addition to assigning simple values like these, Kotlin also lets us assign *functions*. To demonstrate this, here's a simple function to calculate a flat dollar discount, like a $5-off coupon.

```
fun discountFiveDollars(price: Double): Double = price - 5.0
```

*Listing 7.5 - A simple function to take five dollars off of a price.*

Naturally, we can call this function.

```
val discountedPrice = discountFiveDollars(20.0) // Result is 15.0
```

*Listing 7.6 - Calling the function from Listing 7.5.*

In addition to *calling* this function, we can also *assign it to a variable* like this.

```
val applyDiscount = ::discountFiveDollars
```

*Listing 7.7 - Assigning the function from Listing 7.5 to a variable called* **`applyDiscount`**.

Notice the difference between these two lines of code. In Listing 7.6, we're assigning the *result* of a function call, but in Listing 7.7, we're assigning the *function itself*.

In the code above, **`::discountFiveDollars`** is a **function reference**. We call it that because it *refers* to a *function*. By assigning this function to a variable, it's kind of like giving **`discountFiveDollars()`** another name. Now we can call **`applyDiscount()`** the same way that we called **`discountFiveDollars()`**, and it does the same thing.[1]

```
val discountedPrice = applyDiscount(20.0) // Result is 15.0
```

*Listing 7.8 - Calling* **`applyDiscount()`***, which will run the code from* **`discountFiveDollars()`**.

Whether we call **`discountFiveDollars()`** in Listing 7.6 above, or call **`applyDiscount()`** here, the result is the same: **`15.0`** (that is, $15.00).

## Technically Speaking: Member Function References

You can write a function reference like **`::discountFiveDollars`** in many cases, but if you want a reference to a member function (that is, a function that's on an *object*), you'll need to qualify it further.

For example, if you've got an object named **`couponForCustomer`**, and it has a function named **`discount()`**, you can get a reference to it like this:

```
val applyDiscount = couponForCustomer::discount
```

As you might recall, every time that we declare a variable, that variable has a type, even if it's not explicitly written out in the code.

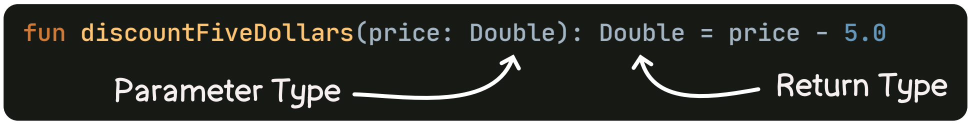
```
val name = "Bert"     // name's type is String
val hasCoupon = true // hasCoupon's type is Boolean
val price = 12.50     // price's type is Double
```

*Listing 7.9 - Examples of type inference.*

[1] Note, however, that we cannot use named arguments when calling a function using the variable's name.

So, you might be wondering about the type of the **`applyDiscount`** variable.

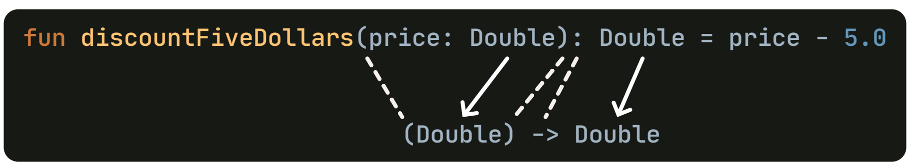
When a variable holds a function, its type is a *combination* of all of its parameter types and its return type. In the case of the **`discountFiveDollars()`** function, these include a single parameter of type **`Double`** and a return type of **`Double`**.




We can assemble a function's type by:

1. Keeping its parentheses.
2. Keeping its types.
3. Converting the colon **`:`** to an arrow **`->`**.

Let's do that with **`discountFiveDollars()`**.

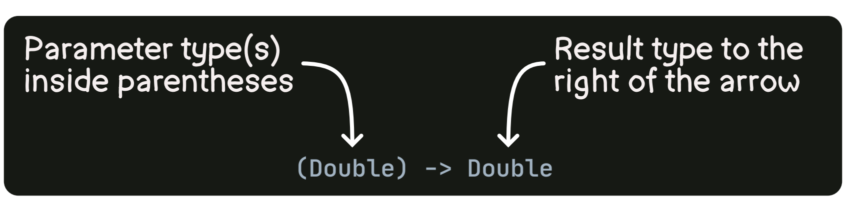



So, the type of **`discountFiveDollars()`** is **`(Double) -> Double`**. Let's write out the type of **`applyDiscount`** explicitly.

```kotlin
val applyDiscount: (Double) -> Double = ::discountFiveDollars
```

*Listing 7.10 - Writing the type of* **`applyDiscount`** *explicitly rather than using type inference.*

All of the types that we've seen up until now, such as **`String`**, **`Int`**, and **`Double`**, have had no spaces or punctuation characters in them. However, **function types** like **`(Double) -> Double`** include more punctuation, and they're a bit long. But, they're easy to figure out! The parameter types go *inside the parentheses*, and the result type goes *to the right of the arrow*.




For functions that have multiple parameters, separate the parameter types with a comma. For example, below is a function that has two parameters—a **`String`** and a **`Double`**—and it returns a **`String`**. When assigning this function to a variable, that variable's type will be **`(String, Double) -> String`** as seen here.

```kotlin
fun menuItemDescription(name: String, price: Double) =
    "A $name costs $price before discounts and tax."

val describeMenuItem: (String, Double) -> String = ::menuItemDescription
```

*Listing 7.11 - Demonstrates a function type that has more than one parameter.*

## Two functions of the same type

As you might recall, when we have *two values of the same type*, such as two **`String`** values, then we can assign (and reassign) those two values to the same variable.

```kotlin
var couponCode = "FIVE_BUCKS"
couponCode = "TAKE_10"
```

*Listing 7.12 - Assigning and reassigning a simple value to a single variable.*

Similarly, if we have two *functions* of the same type—that is, functions that have the same parameter types and return type—then we can assign (and reassign) those two functions to the same variable.

To demonstrate this, let's introduce a function to calculate the discount for a 10%-off coupon. Since it has the same parameter and result types as **`discountFiveDollars()`**, we can assign either of these functions to the same variable.

```kotlin
fun discountFiveDollars(price: Double): Double = price - 5.0
fun discountTenPercent(price: Double): Double = price * 0.9

var applyDiscount = ::discountFiveDollars
applyDiscount = ::discountTenPercent
```

*Listing 7.13 - Assigning and reassigning a function to a single variable.*

Note that the parameter *names* do not have to match. Only the types have to match. The code below works just the same as the code above.

```kotlin
fun discountFiveDollars(initialPrice: Double): Double = initialPrice - 5.0
fun discountTenPercent(originalPrice: Double): Double = originalPrice * 0.9

var applyDiscount = ::discountFiveDollars
applyDiscount = ::discountTenPercent
```

*Listing 7.14 - Assigning functions with different argument names to the same variable.*

For functions that have multiple parameters, keep in mind that the parameters must match *in the same order*.

For example, here are two functions. Both return a **`String`**. Both accept two parameters—one **`String`** and one **`Double`**.

However, since the *order* of those parameters doesn't match, the types of those functions don't match, so we can't assign them to the same variable, or else we'll get an error.

```
fun menuItemDescription(name: String, price: Double) =
    "A $name costs $price before discounts and tax."

fun sillyMenuItemDescription(price: Double, name: String) =
    "You want a $name? It's gonna run you $price, not counting coupons, tax, and more!"

var describeMenuItem = ::menuItemDescription
describeMenuItem = ::sillyMenuItemDescription
```

*Listing 7.15 - **Error:** "Type Mismatch" (does not compile).*

Now that we've seen how we can assign a function to a *variable*, let's move on to a scenario that's even more interesting—assigning a function to a *parameter*. In other words, we'll pass a function as an argument to another function. This is exactly what Bert needed way back in Listing 7.4.

## Passing Functions to Functions

Let's update Bert's **`calculateTotal()`** function to include the correct function type. We'll take the code from Listing 7.4 above and just give the **`applyDiscount`** parameter a function type of **`(Double) -> Double`**.

```
fun calculateTotal(initialPrice: Double, applyDiscount: (Double) -> Double): Double {
    val priceAfterDiscount = applyDiscount(initialPrice)
    val total = priceAfterDiscount * taxMultiplier
    return total
}
```

*Listing 7.16 - A working version of the code in Listing 7.4.*

With this code in place, Bert can call **`calculateTotal()`** with a function reference! Let's define a few more functions that match the type **`(Double) -> Double`**, and then call **`calculateTotal()`** with each of them.

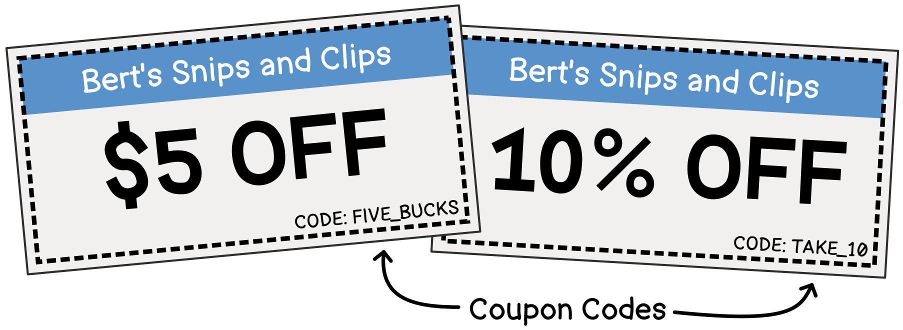
```
fun discountFiveDollars(price: Double): Double = price - 5.0
fun discountTenPercent(price: Double): Double = price * 0.9
fun noDiscount(price: Double): Double = price

val withFiveDollarsOff = calculateTotal(20.0, ::discountFiveDollars) // $16.35
val withTenPercentOff  = calculateTotal(20.0, ::discountTenPercent)  // $19.62
val fullPrice          = calculateTotal(20.0, ::noDiscount)          // $21.80
```

*Listing 7.17 - Calling **`calculateTotal()`** with a variety of function references.*

Great! Bert is now able to calculate the total for different types of coupons, without needing to create multiple versions of **`calculateTotal()`** for each one!

## Returning Functions from Functions

Instead of typing in the *name of the function* each time he calls **`calculateTotal()`**, Bert would like to just enter the *coupon code* from the bottom of the coupon that he receives from the customer.




To do this, he just needs a function that accepts the coupon code and returns the right discount function. In other words, it'll have one parameter that's a **`String`**, and its return type will be **`(Double) -> Double`**.

A [**`when`** expression]() makes this function easy!

```
fun discount(couponCode: String): (Double) -> Double = when (couponCode) {
    "FIVE_BUCKS" -> ::discountFiveDollars
    "TAKE_10"    -> ::discountTenPercent
    else         -> ::noDiscount
}
```

*Listing 7.18 - Returning function references from a function.*

And, of course, we can update Listing 7.17 to use the new **`discount()`** function.

```
val withFiveDollarsOff = calculateTotal(20.0, discount("FIVE_BUCKS")) // $16.35
val withTenPercentOff  = calculateTotal(20.0, discount("TAKE_10"))    // $19.62
val fullPrice          = calculateTotal(20.0, discount("NONE"))       // $21.80
```

*Listing 7.19 - Rewriting the second half of Listing 7.17 to use* **`discount()`**.

Functions like **`calculateTotal()`** and **`discount()`** above, which accept functions as arguments or return them as results, are called **higher-order functions**.

This is a higher-order function because it accepts a function.

```
fun calculateTotal(initialPrice: Double, applyDiscount: (Double) - > Double): Double {
    val priceAfterDiscount = applyDiscount(initialPrice)
    val total = priceAfterDiscount * taxMultiplier
    return total
}
```

This is a higher-order function because it returns a function.

```
fun discount(couponCode: String): (Double) - > Double = when (couponCode) {
    "FIVE_BUCKS" -> ::discountFiveDollars
    "TAKE_TEN"   -> ::discountTenPercent
    else         -> ::noDiscount
}
```

So far, we've been able to achieve a lot with function references! They can be quite helpful when you've already written the function that you want to reference. But Kotlin also gives us another, more concise way to assign functions to variables and parameters—*lambdas!*

# Introduction to Lambdas

As you might recall from Chapter 1, when we write out a value directly in the code, it's called a literal. For example, in Kotlin, we can write literals for basic types such as **`String`**, **`Int`**, and **`Boolean`**. The highlighted parts of the code below are values that are written as literals.

```
val string: String = "This is a string"
val integer: Int = 49
val boolean: Boolean = true
```

*Listing 7.20 - Code that includes literals.*

Just as we can write literals of **`String`**, **`Int`**, and **`Boolean`**, we can also write a literal of a *function*!

"Wait," I can hear you say, "we've already been writing functions! How is this any different?"

Yes, we've been writing named functions with the **`fun`** keyword, but we've never defined a function *directly in an expression*, such as on the right-hand side of an assignment, or directly inside a function call.

We want to define a function directly here or here.

```
val applyDiscount = ____________
val withFiveDollarsOff = calculateTotal(20.0, __________)
```

Let's take another look at the **`discountFiveDollars()`** function from earlier in this chapter. We defined that function and then assigned it to a variable by using a function reference. Here's what it looked like.

```
fun discountFiveDollars(price: Double) = price - 5.0
val applyDiscount: (Double) -> Double = ::discountFiveDollars
```

*Listing 7.21 - Code from Listing 7.5 and 7.7 (with some changes to type inference).*

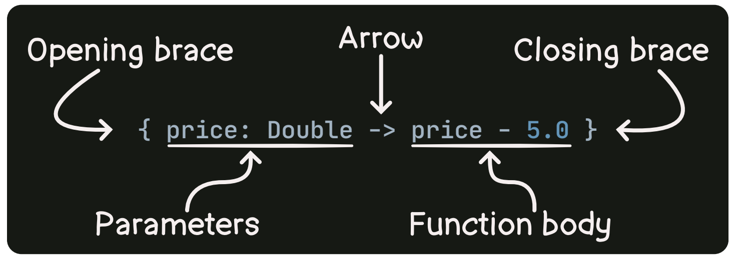
Instead of defining the **`discountFiveDollars()`** function with the **`fun`** keyword, we can rewrite it as a **function literal** like this.

```
val applyDiscount: (Double) -> Double = { price: Double -> price - 5.0 }
```

*Listing 7.22 - Code that includes a function literal instead of a function reference.*

The highlighted part of the code above is a function literal. In Kotlin, a function literal written like this is called a **lambda**.

Lambdas are functions, just like all the other functions we've written so far. They're simply expressed differently.




To write a lambda:

- Use an opening brace **`{`** and a closing brace **`}`**.
- Write the parameters before the arrow **`->`** and the body after the arrow.

Once we've assigned a lambda to a variable, we can call it using the variable's name. Listing 7.21 and Listing 7.22 accomplish the same thing, but the latter does it more concisely.

## Traditional Functions vs Lambdas

Both traditional functions and lambdas have *parameters* and a *body*, and evaluate to some kind of *result*. However, unlike traditional functions, the lambda itself does not have a name. Sure, you can choose to assign it to a *variable* that has a name, but the lambda itself is nameless.

### By the Way: Anonymous Functions

Because lambdas have no name, many programming languages regard lambdas as *anonymous functions*. However, in Kotlin, the term **anonymous function** usually refers to *another* way of writing function literals. The second line below is an anonymous function:

```
val applyDiscount: (Double) -> Double =
    fun(price: Double): Double { return price - 5.0 }
```

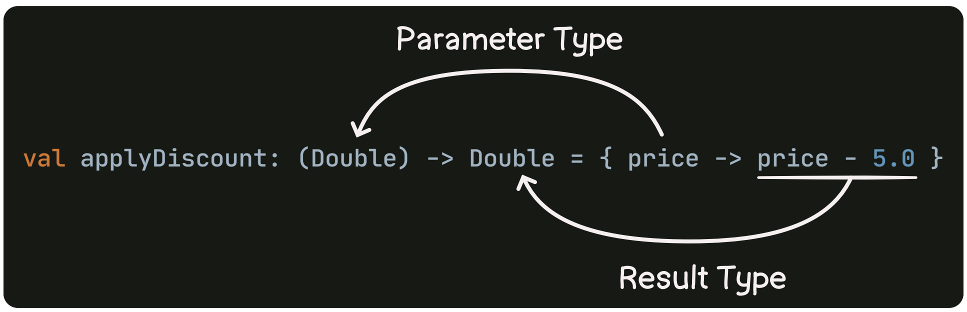
In Kotlin, lambdas are much more widely used than anonymous functions, so we'll focus on them in this book.

The lambda in Listing 7.22 indicates that the **`price`** parameter has a type of **`Double`**. Most of the time, however, Kotlin can use its type inference to figure it out. For example, we can rewrite that listing and omit the parameter's type in the lambda.

```
val applyDiscount: (Double) -> Double = { price -> price - 5.0 }
```

*Listing 7.23 - Same as Listing 7.22, but using type inference on the lambda parameter.*

Kotlin knows that **`price`** must be a **`Double`**, because that's what the type of **`applyDiscount`** says it must be. Similarly, the result type of the lambda has to match.




So, lambdas are a concise way to create a function right in the middle of an expression. Our lambda above is pretty small already, but we can make it even *more* concise!

# The Implicit `it` parameter

In cases where there's only a *single parameter* for a lambda, we can *omit the parameter name and the arrow*. When we do this, Kotlin will automatically make the name of the parameter **`it`**. Let's rewrite our lambda to take advantage of this.

```
val applyDiscount: (Double) -> Double = { it - 5.0 }
```

*Listing 7.24 - Rewriting Listing 7.23 to use the implicit **`it`** parameter.*

The code here is incredibly more concise than the original **`discountFiveDollars()`** function in Listing 7.5.

The implicit **`it`** parameter is used often in Kotlin, especially when the lambda is small, like this one. In cases when the lambda is longer, as we'll see in a moment, it can be a good idea to explicitly name the parameter. Similarly, when one lambda is nested inside another, an explicit parameter name is helpful to avoid confusion.

In many cases, though, the implicit **`it`** parameter can make the code easier to read.

Assigning a lambda to a variable can be helpful, but things get even more interesting when we start using lambdas with higher-order functions!

# Lambdas and Higher-Order Functions

## Passing Lambdas as Arguments

As we learned above, higher-order functions are those that have a function as an input (i.e., parameter) or an output (i.e., the result). Here's the code from Listing 7.16 and Listing 7.17 above, where we used function references to pass functions as arguments to the **`calculateTotal()`** function.

```
fun calculateTotal(initialPrice: Double, applyDiscount: (Double) -> Double): Double {
    val priceAfterDiscount = applyDiscount(initialPrice)
    val total = priceAfterDiscount * taxMultiplier
    return total
}

fun discountFiveDollars(price: Double): Double = price - 5.0
fun discountTenPercent(price: Double): Double = price * 0.9
fun noDiscount(price: Double): Double = price

val withFiveDollarsOff = calculateTotal(20.0, ::discountFiveDollars) // $16.35
val withTenPercentOff  = calculateTotal(20.0, ::discountTenPercent)  // $19.62
val fullPrice          = calculateTotal(20.0, ::noDiscount)          // $21.80
```

*Listing 7.25 - Code from Listing 7.16 and 7.17.*

It's easy to call **`calculateTotal()`** with a lambda instead of a function reference. Let's rewrite the last few lines of the code above to use lambdas. We'll just take the body from each corresponding function and write it as a lambda instead.

```
val withFiveDollarsOff = calculateTotal(20.0, { price -> price - 5.0 }) // $16.35
val withTenPercentOff  = calculateTotal(20.0, { price -> price * 0.9 }) // $19.62
val fullPrice          = calculateTotal(20.0, { price -> price })       // $21.80
```

*Listing 7.26 - Replacing the function references from Listing 7.25 with lambdas.*

In cases where the function's *last parameter* is a function type, we can move the lambda argument *outside* of the parentheses to the right, like this.

```
val withFiveDollarsOff = calculateTotal(20.0) { price -> price - 5.0 } // $16.35
val withTenPercentOff  = calculateTotal(20.0) { price -> price * 0.9 } // $19.62
val fullPrice          = calculateTotal(20.0) { price -> price }       // $21.80
```

*Listing 7.27 - Placing a lambda argument outside of the parentheses.*

Note that we're still sending *two* arguments to **`calculateTotal()`** here. The first is *inside* the parentheses, and the second is *outside* to the right.

First argument (initialPrice)

```
val withFiveDollarsOff = calculateTotal(20.0) { price -> price - 5.0 }
```

Second argument (applyDiscount)

In Kotlin, writing a lambda outside of the parentheses like this is called **trailing lambda syntax**. Regardless of whether we put that last lambda argument inside the parentheses or outside, it works exactly the same. Kotlin developers usually prefer trailing lambdas, though.

Trailing lambda syntax is even more fun when the lambda is the *only* argument that we're passing to the function, because then we can *omit the parentheses completely!*

For example, here's a higher-order function with a single parameter, which has a function type.

```
fun printSubtotal(applyDiscount: (Double) -> Double) {
    val result = applyDiscount(20.0)
    val formatted = "$%.2f".format(result)
    println("A $20.00 haircut will cost you $formatted before tax.")
}
```

*Listing 7.28 - A higher-order function with a single parameter, which is of a function type.*

When calling `printSubtotal()`, no parentheses are needed!

```
printSubtotal { price -> price - 5.0 }
printSubtotal { price -> price * 0.9 }
```

*Listing 7.29 - Calling* `printSubtotal()` *without parentheses.*

## Returning Lambdas as Function Results

In addition to using lambdas as arguments, we can also use them as function results. Here's the code from Listing 7.18 above, where we returned function references.

```
fun discount(couponCode: String): (Double) -> Double = when (couponCode) {
    "FIVE_BUCKS" -> ::discountFiveDollars
    "TAKE_10"    -> ::discountTenPercent
    else         -> ::noDiscount
}
```

*Listing 7.30 - Returning function references from a function. (Same as Listing 7.18).*

We can very easily replace these function references with lambdas, just as we did for the function arguments in Listing 7.27.

```
fun discount(couponCode: String): (Double) -> Double = when (couponCode) {
    "FIVE_BUCKS" -> { price -> price - 5.0 }
    "TAKE_10"    -> { price -> price * 0.9 }
    else         -> { price -> price }
}
```

*Listing 7.31 - Returning lambdas from a function.*

# Lambdas with Multiple Statements

So far, the lambdas that we've created have contained *only one simple expression* each. But sometimes we need a lambda that has *multiple statements* in it.

To do this, simply put each statement on a separate line, as we would do in any other function. Unlike in a regular function, though, we don't use the **return** keyword to return the result. Instead, the very last line of the lambda will be the result of the call.

For example, we might want to print some pricing details inside our lambda that calculates the five-dollars-off coupon. Here's how we can do that.

```
val withFiveDollarsOff = calculateTotal(20.0) { price ->
    val result = price - 5.0
    println("Initial price: $price")
    println("Discounted price: $result")
    result
}
```

*Listing 7.32 - A lambda that has multiple lines of code.*

When we've got a lambda that spans multiple lines like this, it's conventional to put the parameters and arrow on the same line as the opening brace, as seen above.

Here's the same code, with some notes indicating each part.

Parameter and arrow

```
val withFiveDollarsOff = calculateTotal(20.0) { price ->
    val discountedPrice = price - 5.0
    println("Initial price: $price")
    println("Discounted price: $discountedPrice")
    discountedPrice
}
```

Multiple statements

Result (no "return" keyword!)

Before we wrap up this chapter, we've got one more concept to cover—closures!

# Closures

Bert's barber shop is doing great now!

Let's take a look at his code, including **`calculateTotal()`**, **`discount()`**, and how he ends up calling them to get the total.

```
fun calculateTotal(initialPrice: Double, applyDiscount: (Double) -> Double): Double {
    val priceAfterDiscount = applyDiscount(initialPrice)
    val total = priceAfterDiscount * taxMultiplier
    return total
}

fun discount(couponCode: String): (Double) -> Double = when (couponCode) {
    "FIVE_BUCKS" -> { price -> price - 5.0 }
    "TAKE_10"    -> { price -> price * 0.9 }
    else         -> { price -> price }
}

val initialPrice = 20.0
val couponDiscount = discount("FIVE_BUCKS")
val total = calculateTotal(initialPrice, couponDiscount)
```

*Listing 7.33 - Putting it all together.*

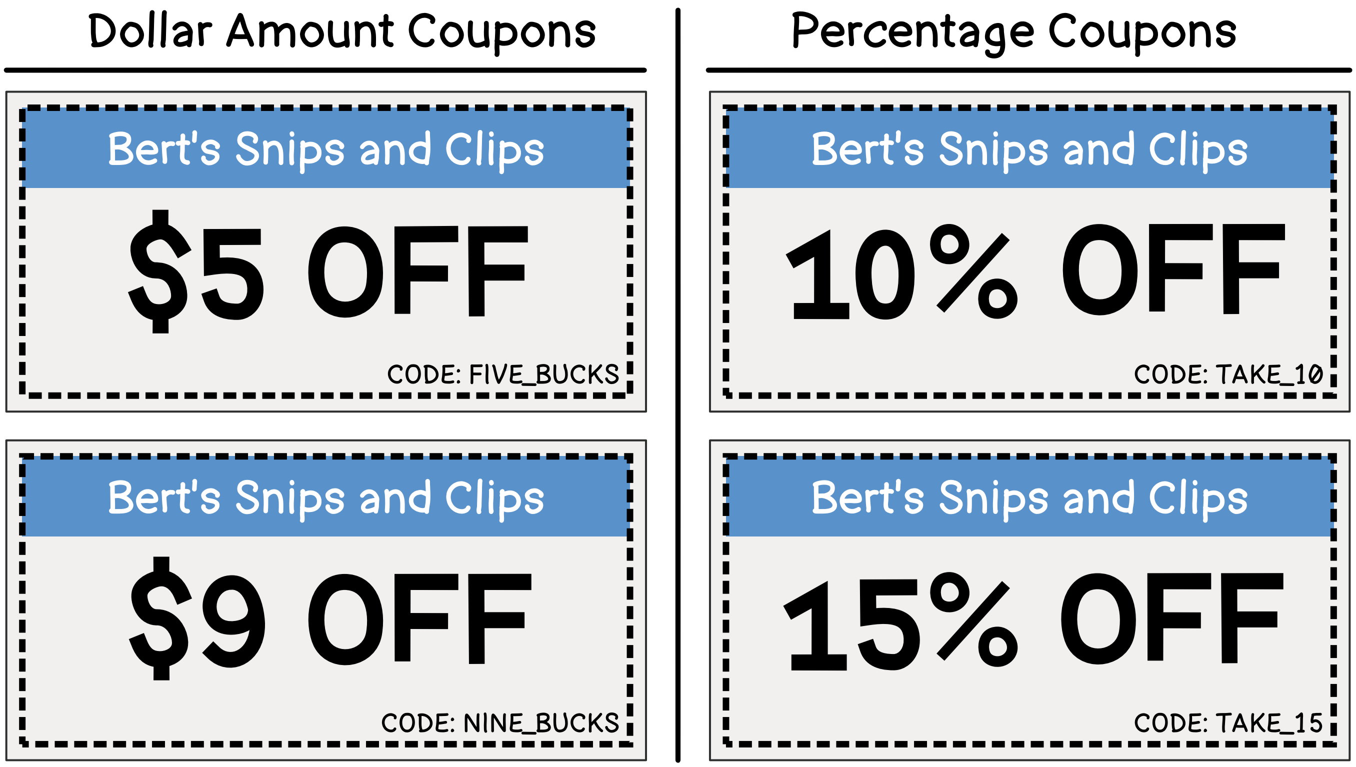
Bert noticed that whenever he introduces a new coupon, he needs to write another lambda.

For example, if he were to add a new coupon for nine dollars off, and another one for fifteen percent off, he would need to write a few more lambdas.

```
fun discount(couponCode: String): (Double) -> Double = when (couponCode) {
    "FIVE_BUCKS" -> { price -> price - 5.0 }
    "NINE_BUCKS" -> { price -> price - 9.0 }
    "TAKE_10"    -> { price -> price * 0.9 }
    "TAKE_15"    -> { price -> price * 0.85 }
    else         -> { price -> price }
}
```

*Listing 7.34 - Adding more coupon codes.*

That's not too bad, but he decided he could make one last small improvement. There are really two main categories of coupons—dollar amount and percentages.




He wrote the two functions in Listing 7.35 below—**`amountDiscount()`** and **`percentageDiscount()`**—to match the two categories of coupons that he identified.

It's important to note that these two functions *do not calculate the discount* themselves. Instead, they *create functions* that calculate the discount. This is a little easier to see in **`percentageDiscount()`**, where he's using an explicit **`return`** keyword rather than an expression body.

```
fun amountDiscount(amountOff: Double): (Double) -> Double =
    { price -> price - amountOff }

fun percentageDiscount(percentageOff: Double): (Double) -> Double {
    val multiplier = 1.0 - percentageOff
    return { price -> price * multiplier }
}
```

*Listing 7.35 - Functions that create functions.*

Another neat thing here is that these lambdas use variables that are *defined outside of the lambda body*. The first one uses the **`amountOff`** parameter of the wrapping function, and the second uses the **`multiplier`** variable.

When a lambda uses a variable that's defined *outside of its body* like this, it's sometimes referred to as a **closure**. In this code, **`multiplier`** is a read-only variable declared with **`val`**. But if it were declared with **`var`**, it would also be possible for the code in the lambda to change the value of that variable.

With these two functions, creating a new coupon is easy. Instead of writing the lambda inline in `discount()`, Bert can just call either `amountDiscount()` or `percentageDiscount()` to create the lambda for him.

```
fun discount(couponCode: String): (Double) -> Double = when (couponCode) {
    "FIVE_BUCKS" -> amountDiscount(5.0)
    "NINE_BUCKS" -> amountDiscount(9.0)
    "TAKE_10"    -> percentageDiscount(0.10)
    "TAKE_15"    -> percentageDiscount(0.15)
    else         -> { price -> price }
}
```

*Listing 7.36 - A small improvement to avoid some duplicated code.*

# Summary

Thanks to Kotlin's lambdas and function references, Bert can now create coupons for a wide range of amounts and percentages, while shearing away duplicate functions!

Congratulations on completing this chapter! Lambdas can be a tough concept for many programmers who haven't used them before. If you still feel a little unsure about them, it's completely fine. We'll use them a lot in upcoming chapters, and you'll get more familiar with them as you go.

In this chapter, you learned about:

- Function types, like `(Int, Int) -> Int`.
- Function references, which let you assign existing functions to variables and parameters.
- Lambdas, which are literals for functions.
- Higher-order functions, which are functions that accept a function as an argument, or return one as a result.
- The implicit it parameter, which can be used when a lambda has a single parameter.
- Multiple-line lambdas, which can be useful when your lambda needs more than just a single expression.
- Closures, which allow us to read and change the value of variables declared outside of the lambda.

Throughout this chapter, we've seen some simple use cases for lambdas, but they *really* shine when used with *collections*. In the next chapter, we'll introduce collections, and we'll see how we can use lambdas to do all sorts of fun things with them!

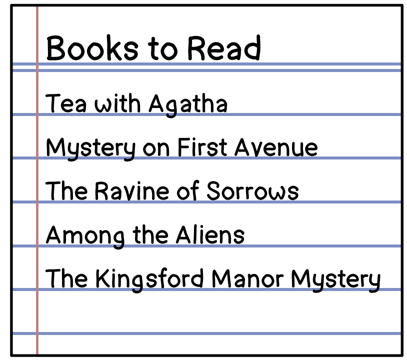
# Collections: Lists and Sets

## Let’s put things together!

So far, we’ve only worked with variables as individual values. Writing Kotlin becomes so much more interesting once we start putting variables together in a way that we can work with them as a collection.

To learn about collections, let’s visit Libby, a bright young lady who’s always got a book nearby!

Libby is a voracious reader. She's always on the lookout for a great novel, so whenever someone tells her about a good book, she jots down the title on a list that she keeps on a sheet of paper. Here are the titles that are currently on her list.




Libby has been learning to write Kotlin code in her spare time, so she also wanted to write this same list in Kotlin, and print all of the titles to the screen.

Here's what she wrote.

```
val book1 = "Tea with Agatha"
val book2 = "Mystery on First Avenue"
val book3 = "The Ravine of Sorrows"
val book4 = "Among the Aliens"
val book5 = "The Kingsford Manor Mystery"

println(book1)
println(book2)
println(book3)
println(book4)
println(book5)
```

*Listing 8.1 - Creating multiple strings to represent titles of books.*

"Hmm…", she thought. "Every time I add a new book, I have to create a new variable. And keeping the numbers in order could be hard—if I remove **`book3`** from the middle of the list, then **`book4`** and **`book5`** would need to be renamed to **`book3`** and **`book4`**. If only there were a better way to keep track of my list of book titles…"

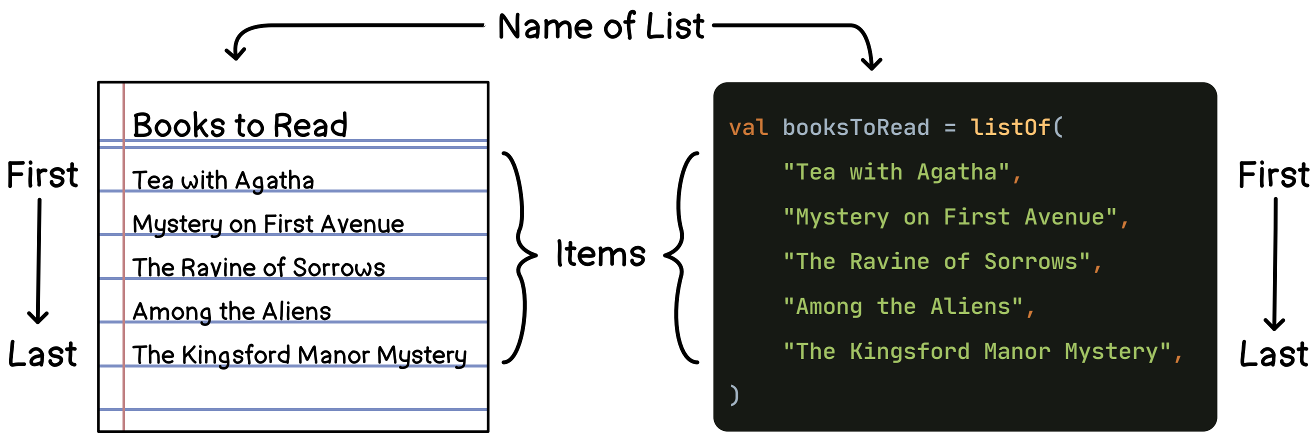
# Introduction to Lists

Thankfully, there's a *much* better way! Libby can create a **collection**. Let's start with one of the most common kinds of collections in Kotlin—a **list**. Creating a list is easy—just call **`listOf()`** with the values that you want, separating them with commas. Let's update Libby's code so that it's using a list.

```
val booksToRead = listOf(
    "Tea with Agatha",
    "Mystery on First Avenue",
    "The Ravine of Sorrows",
    "Among the Aliens",
    "The Kingsford Manor Mystery",
)
```

*Listing 8.2 - Creating a list of strings to represent titles of books.*

This code looks pretty similar to Libby's handwritten list. In fact, let's compare the two!




The handwritten list and the Kotlin list have a lot in common.

1. First, they both have a *name*. In Kotlin, the name of the list variable is kind of like the name of the list on paper.

2. Next, both lists have *items* in them—in this case, the titles of the books. In Kotlin, the items in a list are called **elements**.

3. Finally, both lists have the titles in a particular *order*.

In the past, we've used the **`println()`** function to print out the contents of a variable to the screen. We can also use **`println()`** with a collection variable.

```
println(booksToRead)
```

*Listing 8.3 - Printing a collection variable to the screen.*

When we do this, we'll see its elements in order.

```
[Tea with Agatha, Mystery on First Avenue, The Ravine of Sorrows, Among the Aliens,
The Kingsford Manor Mystery]
```

## Collections and Types

When working with collections in Kotlin, we have *two* different types to consider.

1. The type of the *collection* we're using.
2. The type of the *elements* in the collection.

These two things together determine the overall type of the collection variable. In the case of Listing 8.2:

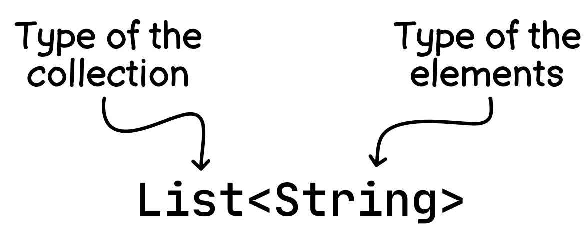
1. The type of the collection is `List`.
2. The type of the elements in the collection is `String`.

The kind of collection we're using is a List

```
val booksToRead = listOf(
    "Tea with Agatha",
    "Mystery on First Avenue",
    "The Ravine of Sorrows",
    "Among the Aliens",
    "The Kingsford Manor Mystery",
)
```

Each of these elements is a String

Once we know these two things, we can write the type of a collection variable easily. Just put the type of the collection first, then write the type of the elements second, between a left angle bracket `<` and a right angle bracket `>`. So the type of `booksToRead` is `List<String>`.




Let's rewrite Listing 8.2, this time explicitly including the type information for the `booksToRead` collection variable.

```
val booksToRead: List<String> = listOf(
    "Tea with Agatha",
    "Mystery on First Avenue",
    "The Ravine of Sorrows",
    "Among the Aliens",
    "The Kingsford Manor Mystery",
)
```

*Listing 8.4 - Explicitly including the type of a collection variable.*

This kind of a type is known as a **generic**. We will cover generics in detail in Chapter 18. For now, it's just important to know how to write the type for a list, in case you need to use it as a function's parameter type or return type.

## Adding and Removing an Element

Libby just heard about another great book from her friend, Rebecca! She's ready to add this new title, *Beyond the Expanse*, to her list. How can she do this?

Of course, she could just add one more argument to the end of `listOf()`. But what about adding the title *after* the list has already been created?

In Kotlin, once we've already called `listOf()` to create a list, that list can't be changed. We can't add anything to it, and we can't remove anything from it. The fancy word for "change" in programming is **mutate**, so a list that doesn't allow us to add or remove elements is called an **immutable list**.[1]

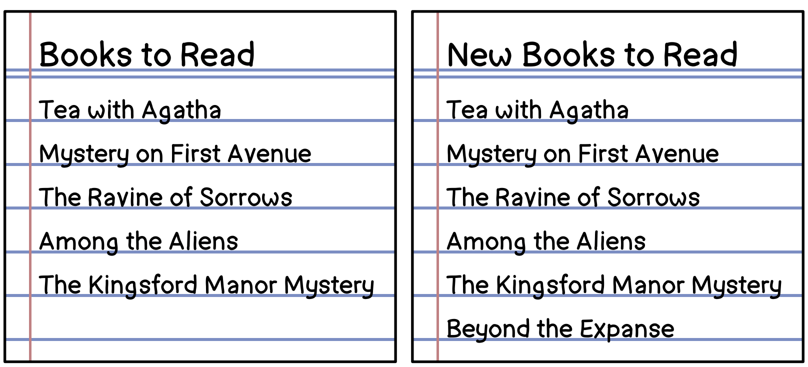
Even though we can't add or remove elements from a regular Kotlin `List`, we can *create a new list* by putting the original list together with a new element. To do this, use the **plus operator**. That is, use **+** to connect the original list with the new item, and assign it to a new variable.

```
val booksToRead = listOf(
    "Tea with Agatha",
    "Mystery on First Avenue",
    "The Ravine of Sorrows",
    "Among the Aliens",
    "The Kingsford Manor Mystery",
)

val newBooksToRead = booksToRead + "Beyond the Expanse"
```

*Listing 8.5 - Creating a new list that combines a list with one new element.*

In this code, the highlighted code is an expression that evaluates to a new `List` instance. So, by the time this code is done running, we have *two collection variables*—`booksToRead` and `newBooksToRead`.

This is kind of writing the new list of titles on a second sheet of paper. That way, Libby actually ends up with *two lists*—the original list and the new list.




As you remember from Chapter 1, a variable can be declared with either `val` or `var`, and this includes variables that hold a collection. Keep in mind, though, that declaring a collection variable with `var` does not change the fact that *the list itself is immutable*. In other words, just declaring it with `var` does not make it so that you can add or remove elements. However, `var` *does* let you assign *another* immutable list to it.

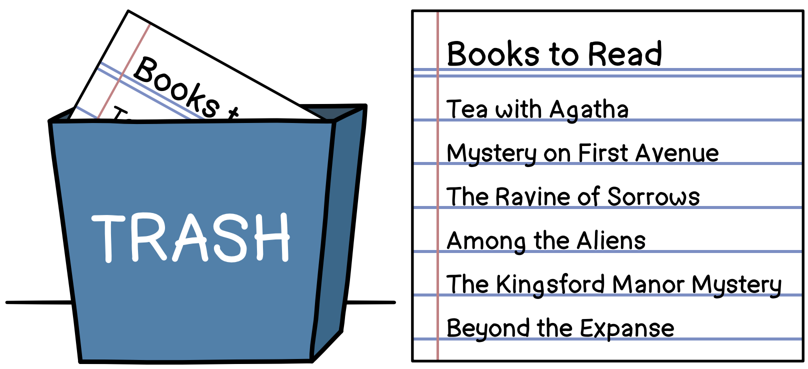
[1] Technically, a List is not guaranteed to be immutable. Depending on the particular instance of the list, it might be possible to cast it to a MutableList and then make changes to it. In Chapters 12 and later, we'll learn about subtypes, supertypes, and casting. But for now, we'll regard a List as immutable, because it can't be mutated in its current form.

So by changing the **booksToRead** variable from **val** to **var**, the new list can be assigned to the *existing* variable.

```
var booksToRead = listOf(
    "Tea with Agatha",
    "Mystery on First Avenue",
    "The Ravine of Sorrows",
    "Among the Aliens",
    "The Kingsford Manor Mystery",
)

booksToRead = booksToRead + "Beyond the Expanse"
```

*Listing 8.6 - Reassigning the collection to the existing **booksToRead** variable.*

This is kind of like throwing the old paper list in the trash, and simply giving the new list the same name as the old one.




Libby's list now has six titles in it. Just when she thought she was done updating the list, she heard from Rebecca again. "You know, I read *Among the Aliens* last week. It really wasn't very good," she said. "You shouldn't bother reading that one."

Libby would like to scratch that one off her list. The way we remove an element is similar to the way we added an element above, but instead of using the plus operator, we use the **minus operator**.

```
var booksToRead = listOf(
    "Tea with Agatha",
    "Mystery on First Avenue",
    "The Ravine of Sorrows",
    "Among the Aliens",
    "The Kingsford Manor Mystery",
)

booksToRead = booksToRead + "Beyond the Expanse"
booksToRead = booksToRead - "Among the Aliens"
```

*Listing 8.7 - Adding and removing an element from a collection.*

In fact, those last two lines can be consolidated, like this.

```
booksToRead = booksToRead + "Beyond the Expanse" - "Among the Aliens"
```

*Listing 8.8 - Adding and removing an element from a collection with one assignment.*

With this change, if Libby writes **`println(booksToRead)`**, she would see this on the screen.

```
[Tea with Agatha, Mystery on First Avenue, The Ravine of Sorrows,
The Kingsford Manor Mystery, Beyond the Expanse]
```

"Excellent!" she thought, "My reading list is all up to date!"

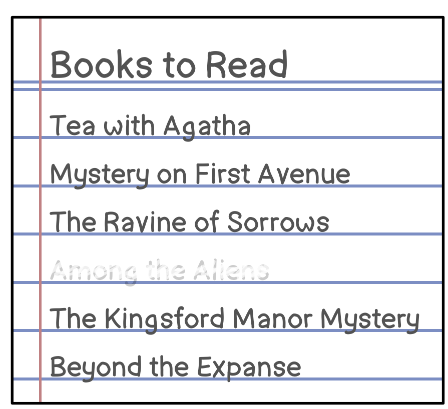
## List and MutableList

So far, we've been using a regular Kotlin **`List`**, which doesn't allow changes to it, as we saw above. Instead, we had to create a new list by using a plus or minus operator.

However, Kotlin also provides another kind of list—one that *does* allow you to change it. Since these lists do allow changes, they're called **mutable lists**, and their type is **`MutableList`**.

```
var booksToRead: MutableList<String> = mutableListOf(
    "Tea with Agatha",
    "Mystery on First Avenue",
    "The Ravine of Sorrows",
    "Among the Aliens",
    "The Kingsford Manor Mystery",
)

booksToRead.add("Beyond the Expanse")
booksToRead.remove("Among the Aliens")
```

*Listing 8.9 - Creating, adding to, and removing from a mutable list.*




A mutable list can be created with a function named **`mutableListOf()`**. When *using* a mutable list, we can use the **`add()`** and **`remove()`** functions to add or remove elements

Using a mutable list is kind of like Libby writing down her paper list with a pencil instead of a pen.

She can go in and erase a title, or add another, without using another sheet of paper.

## Heads Up: Using Plus and Minus Operators with a Mutable List

For what it's worth, you can also use the plus and minus operators on a mutable list, but keep in mind that those expressions evaluate to a regular immutable `List`, not `MutableList`. So generally, if you're using a `List`, use the plus and minus operators, and if you're using a `MutableList`, use the `add()` and `remove()` functions.

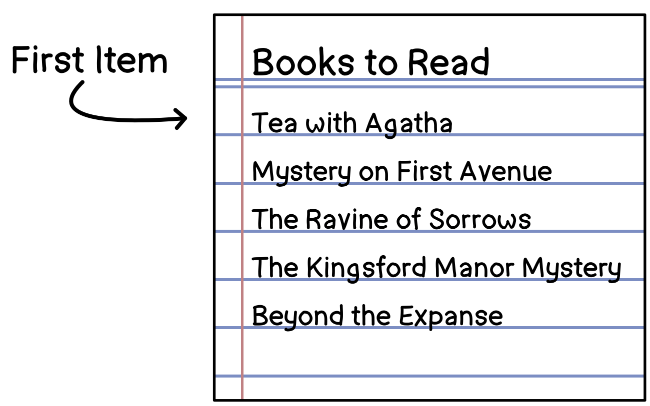
## Best Practice: List or Mutable List?

`MutableList` can be convenient, and if you need to add or remove lots of elements, it can also be faster than a regular `List`. However, similar to the trade-offs of using `val` versus `var`, it's often better to stick with things that can't change, because when something can't change, you have guarantees that you wouldn't have otherwise. Sometimes this guarantee is very helpful, and other times it might not be as important. Use whatever is most appropriate for each situation, but by default, go with a regular `List`.

Libby is ready to start reading those books! But in order know which book to start with, she needs to know how to get a single title out of the list.

## Getting an Element from a List

"All right, which title is first on my list?" wondered Libby. She glanced down at her handwritten page. It was easy for her to see which one was first. "Tea with Agatha," she noted. "Now how do I get the first title from the list in Kotlin?"




As mentioned earlier, the elements of a list are in a particular order, and that order is *very* important for getting an individual element out of the list.

Here's how it works. Each element in the list is given a number, called an **index**, based on where it is in the list. The first element has an index of 0, the second has an index of 1, the third has an index of 2, and so on.

```
     val booksToRead = listOf(
0 ---- "Tea with Agatha",
1 ---- "Mystery on First Avenue",
2 ---- "The Ravine of Sorrows",
3 ---- "The Kingsford Manor Mystery",
4 ---- "Beyond the Expanse"
     )
```

It's easy to get an element out of a list once you know its index. Just call the **`get()`** member function, passing the index as the argument. For example, Libby can get the *first* element out of the list by calling **`get(0)`**.

```kotlin
val booksToRead = listOf(
    "Tea with Agatha",
    "Mystery on First Avenue",
    "The Ravine of Sorrows",
    "The Kingsford Manor Mystery",
    "Beyond the Expanse"
)

val firstBook = booksToRead.get(0)
println(firstBook) // Tea with Agatha
```

*Listing 8.10 - Using the **`get()`** function to get a single element out of a collection.*

"Great!" said Libby. "Now I can easily get a single title out of the list of books!"

## Heads Up: Out-of-Bound Indexes

When you call **`get()`**, make sure that the index you give it is for an element that actually exists! In **`booksToRead`**, there are five elements, so you could call **`get()`** with any number including and between 0 and 4. If you were to call **`get(86)`**, for example, you would see an error message that says that the index was out of bounds.

## Technically Speaking: Why Do Indexes Start with Zero?

Kotlin follows the tradition of many other programming languages in that its indexes start with the number 0 instead of 1. One classic data structure for representing a list of values is called an *array*. In older programming languages, you had to manage the location of your variables and arrays in the computer's memory. A single element of an array took up a certain amount of memory—for example, an integer took up one byte of memory—and an array required a contiguous block of memory. So, if you had an array of integers, they were all physically next to each other in the computer's memory.

If you knew the starting address of the array—that is, the memory address of the first element in the array—you could get any other particular element's memory address by multiplying its index by the size of the individual elements, then adding that to the starting address.

Kotlin doesn't require its developers to manage memory this way, but it does have a few different kinds of lists, each using a different kind of data structure to hold the elements for you behind the scenes. Regardless of whether a particular list uses an array to hold its data, the indexes still always start with zero.

Rather than calling the `get()` function directly, you can use the **indexed access operator** instead, which is written with an opening bracket `[` and a closing bracket `]`, with the index in the middle. The code in the following listing does the exact same thing as the code above.

```
val firstBook = booksToRead[0]
println(firstBook) // Tea with Agatha
```

*Listing 8.11 - Getting a single element out of a collection, using the indexed access operator.*

Kotlin developers use the *indexed access operator* much more than they use the `get()` function, so we'll be using it from now on.

Now, getting an individual item out of the list can be helpful, but collections become *especially* helpful when we want to *do something with each item in the list*. Let's see how to do that next!

# Loops and Iterations

"Now, I'd like to print out the list of books to the screen," said Libby to herself. "I'll use `println(booksToRead)` for this!" Upon running that code, here's what she saw.

```
[Tea with Agatha, Mystery on First Avenue, The Ravine of Sorrows,
The Kingsford Manor Mystery, Beyond the Expanse]
```

"It's nice that I can print out the list so easily, but I'd really like to see the list *vertically*, like my handwritten list." Here's what she has in mind.

```
Tea with Agatha
Mystery on First Avenue
The Ravine of Sorrows
The Kingsford Manor Mystery
Beyond the Expanse
```

Of course, to achieve this, she *could* call `println()` on each element one by one, like this.

```
println(booksToRead[0])
println(booksToRead[1])
println(booksToRead[2])
println(booksToRead[3])
println(booksToRead[4])
```

*Listing 8.12 - Printing each element by hand.*

However, writing code like this is quite tedious. Plus, it would be easy to make a mistake by printing the elements out of order, or by accidentally printing the same element more than once. In fact, this looks a whole lot like the code back in Listing 8.1!

Instead of writing out the same code for each element in the list, what if Kotlin could just go through every element, one by one, and call **`println()`** on each?

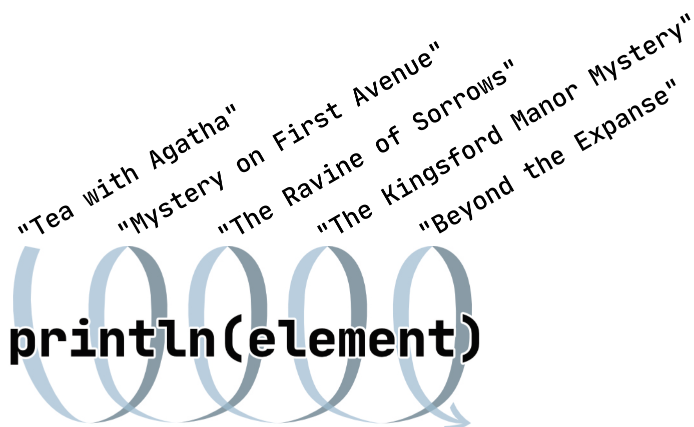
Thankfully, this is very easy to do! We can use the **`forEach()`** function. Here's how it looks.

```
booksToRead.forEach { element ->
    println(element)
}
```

*Listing 8.13 - Using `forEach()` to print each element.*

When Kotlin is executing this code, it runs down through **`println(element)`** for the first element, then comes back up and runs down it again for the second element, then comes back up and runs down it again for the third element, and so on.

By going through this line of code over and over again, it's as if it's looping in circles.




That's why programming languages call this a **loop**—because, for each element in the collection, it cycles back through that code. This process is also called **iterating**, and each time the code in the loop runs, it's a single **iteration**.

## Technically Speaking: Using the Term "Loop"

In a lot of the programming texts out there—including the Kotlin documentation—the term "loop" tends to be reserved for traditional programming constructs like **`for`** or **`while`**, but not used when referring to collection functions like **`forEach()`**. Although Kotlin does support these traditional looping constructs, in this book, we'll stick with **`forEach()`** and similar functions, which we can put together to do all sorts of cool things, as we'll see later in this chapter.

Since we won't need to distinguish between traditional looping constructs and collection functions, and since those collection functions ultimately use a traditional **`for`** loop under the hood anyway, we'll be more liberal with the use of the term "loop" in this book.

Let's look a little closer at **`forEach()`**, to understand why we had to structure the code the way we did.

`forEach()` is a member function that exists on collection variables. It's a higher-order function that accepts a lambda. That lambda is the code that you want Kotlin to run "for each" element in the collection.

Collection variable

Lambda parameter

```
booksToRead.forEach { element ->
    println(element)
}
```

Code to run
for each element

Here we named the parameter `element`, but you could have named it `title` instead. Alternatively, since this lambda has only a single parameter, we can use the implicit `it` parameter instead, which makes it nice and concise. In fact, we can put it all on one line.

```
booksToRead.forEach { println(it) }
```

*Listing 8.14 - Using the implicit* `it` *parameter with* `forEach()`*.*

The result in either case is exactly what Libby wanted—the book titles are printed out vertically, just like on her paper notepad!

```
Tea with Agatha
Mystery on First Avenue
The Ravine of Sorrows
The Kingsford Manor Mystery
Beyond the Expanse
```

### By the Way: Function References

Instead of passing a lambda to `forEach()`, we can also pass it a function reference, as long as the function that we're referring to has the right function type—in our case, it must have a single parameter that accepts a `String`. Since the `println()` function has a single parameter that accepts a `String`, we could have achieved the same thing as Listing 8.13 and Listing 8.14 by simply doing this.

```
booksToRead.forEach(::println)
```

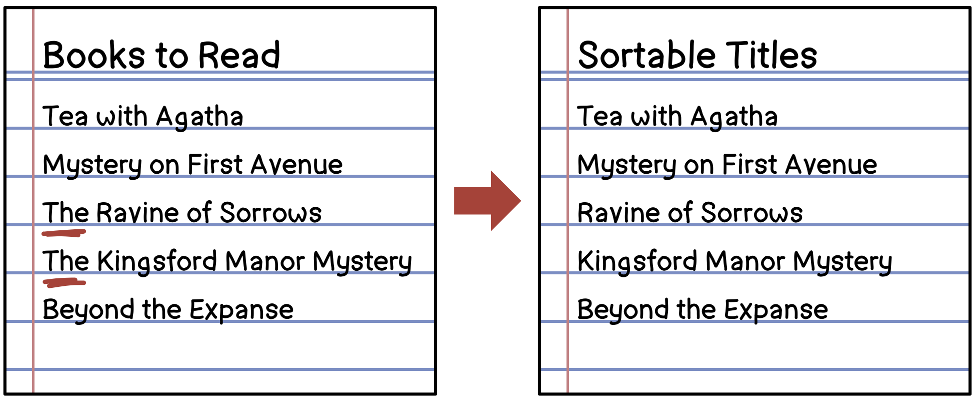
# Collection Operations

Libby is ready to share her list of books with other people who are interested in what she'll be reading, starting with her friend Nolan. However, when she makes a copy of the list for him, she wants to make changes to some of the titles.

"I'd really like to remove the word 'The' from the beginning of each title," thought Libby. "That way, I'll be able to sort it alphabetically, and the titles that begin with 'The' won't clump together."

## Mapping Collections: Converting Elements

Sometimes when we create a new collection from an existing one, we also want to convert one or more of the elements in some way. In Libby's case, she wants to remove the word "The" when it appears at the beginning of a title, so that they could be sorted alphabetically.




Before doing that conversion on *all* of the titles, let's start with just *one* of them. **`String`** objects have a **`removePrefix()`** function, which returns a new string that omits characters from the beginning of the original string. Here's how we can use it.

```
val title = "The Kingsford Manor Mystery"
val sortableTitle = title.removePrefix("The ")

println(sortableTitle) // Kingsford Manor Mystery
```

*Listing 8.15 - Using **`removePrefix()`** on a single string.*

With this code, the original **`title`** string still begins with "The ", but the new **`sortableTitle`** string omits it.

Perfect! Now she just needs to apply this **`removePrefix()`** function to *each element in the list!* "Maybe I can use **`forEach()`**, since I know it operates on each item in the list", thought Libby. She rolled up her sleeves, and cranked out the following code.

```
val sortableTitles: MutableList<String> = mutableListOf()

booksToRead.forEach { title -> sortableTitles.add(title.removePrefix("The ")) }

sortableTitles.forEach { println(it) }
```

*Listing 8.16 - Manually creating a list without the word "The" at the beginning of the titles.*

"Well, that works," thought Libby. "But it's a little complicated, and it's a lot of code to write…"

The reason this is complicated is that Libby wanted to create a new collection, but **`forEach()`** doesn't do that. It simply runs the lambda on an *existing* collection, and then returns [`Unit`](). What she really needs is a function that runs the lambda for each element and includes the result of that lambda as an element in a *new* collection.

In Kotlin, that function is named **`map()`**. Here's how Libby can use it to remove the word "The" from the beginning of titles in the new collection.

```
val sortableTitles = booksToRead.map { title ->
    title.removePrefix("The ")
}
```

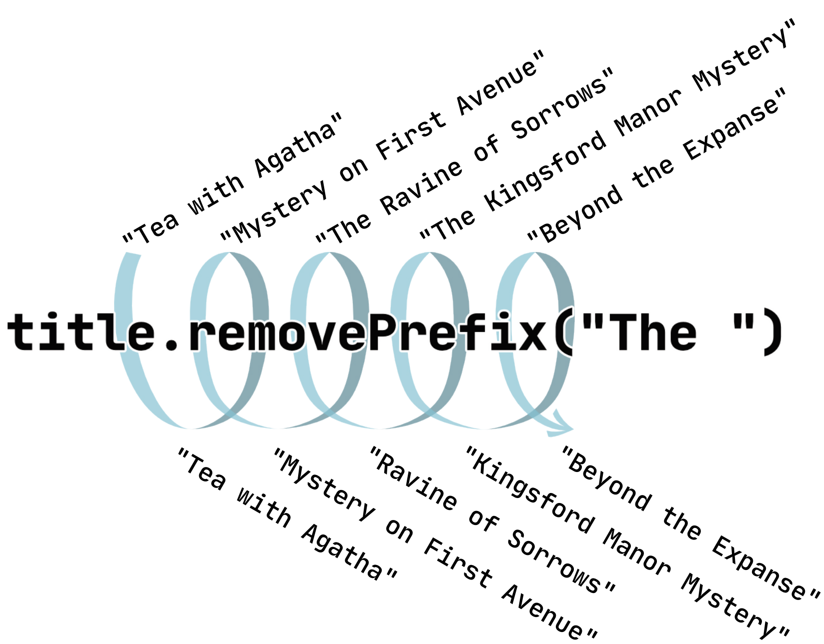
*Listing 8.17 - Using* **`map()`** *to create a list without the word "The" at the beginning of the titles.*

This code does the same thing as the previous listing, except that the result is a regular **`List`** instead of a **`MutableList`**.

Like **`forEach()`**, the **`map()`** function calls the lambda once with each element in the list. However, unlike **`forEach()`**, **`map()`** will use the result of the lambda on each iteration to *build out a new list*.

When we print each element of the list, we can see that both *The Ravine of Sorrows* and *The Kingsford Manor Mystery* have been updated so that the word "The" is not at the beginning.

```
Tea with Agatha
Mystery on First Avenue
Ravine of Sorrows
Kingsford Manor Mystery
Beyond the Expanse
```



Let's take a closer look at the **`map()`** function.

New list variable    Original list variable    Lambda parameter

```
val sortableTitles = booksToRead.map { title ->
    title.removePrefix("The ")
}
```

Evaluates to a value that becomes an element in the new list.

Here are the key takeaways.

- Similar to **`forEach()`**, the **`map()`** function is a higher-order function that takes a lambda.
- That lambda will run once for each element in the list.
- The result of the lambda will be an element in the new collection.
- The **`map()`** function returns that new collection.

Functions like **`forEach()`** and **`map()`** are called **collection operations**, because they're functions that perform some operation on (that is, they do something with) a collection.

"Perfect!" said Libby, "Now that the titles have been changed like I want, maybe I can finally sort them alphabetically!"

## Sorting Collections

The **`forEach()`** and **`map()`** functions are only two of many collection operations in Kotlin. Another one that can be quite helpful is called **`sorted()`**.

Since the **`map()`** function returns a collection, Libby can just call **`sorted()`** immediately after the call to **`map()`**, like this.

```
val sortedTitles = booksToRead.map { title -> title.removePrefix("The ") }.sorted()
```

*Listing 8.18 - Combining* **`map()`** *with* **`sorted()`**.

When she printed out the elements of **`sortedTitles`**, she saw the output she was hoping for!

```
Beyond the Expanse
Kingsford Manor Mystery
Mystery on First Avenue
Ravine of Sorrows
Tea with Agatha
```

In order to make things easier to read, each collection operation can go on its own line.

```kotlin
val sortedTitles = booksToRead
    .map { title -> title.removePrefix("The ") }
    .sorted()
```

*Listing 8.19 - Formatting multiple collection operations so that they line up.*

This code is identical to the previous listing except for the *formatting*. In other words, all of the letters and punctuation are exactly the same and in the same order—it's only the space between them that's different.

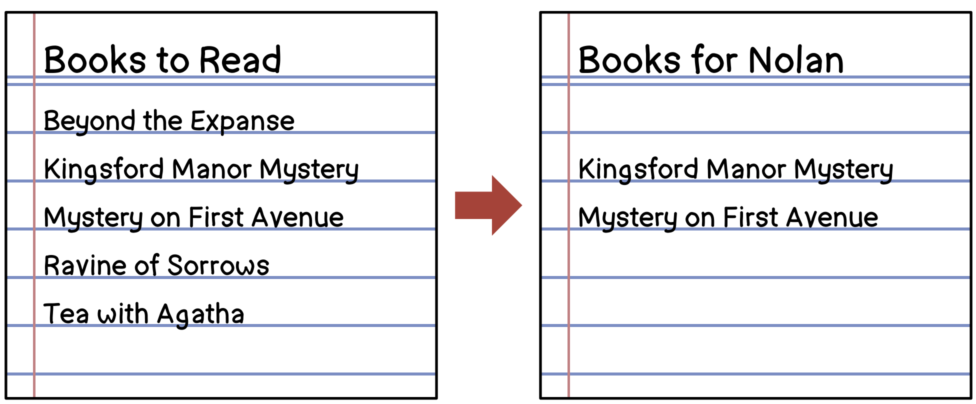
Writing the collection operations vertically like this can be helpful because it makes it easy to scan down the lines to see what collection operations are involved and what order they're in. For example, *first* the titles are mapped, and *then* the titles are sorted. For that reason, Kotlin developers often format their code this way.

## Filtering Collections: Including and Omitting Elements

Libby was excited to have a list of books—sorted alphabetically—to share with Nolan.

"I can't wait to see your list of books," said Nolan. "Just remember—I only read mystery novels!"

"Only mysteries…?" repeated Libby. "Okay," she thought to herself, "the final thing I need to do is remove the titles that are not mysteries." She pulled out a sheet from her notepad, and wrote a customized list just for Nolan, omitting any title that is not a mystery.




"How can I do this in Kotlin?" she wondered.

As you probably guessed, Kotlin includes a collection operation that makes this easy, and unsurprisingly, it's named `filter()`. Just like an air filter that blocks unwanted dust and allergens from getting through to an air conditioner system, a Kotlin list filter blocks elements that we don't want to get through to a new list!

Let's use the `filter()` function to filter down the list of books to just those that have "Mystery" in the title. To achieve this, we'll use a function named `contains()`, which returns a `Boolean` indicating whether any part of the string includes its argument.

```kotlin
val title = "Mystery on First Avenue"

title.contains("Avenue") // true
title.contains("Street") // false
```

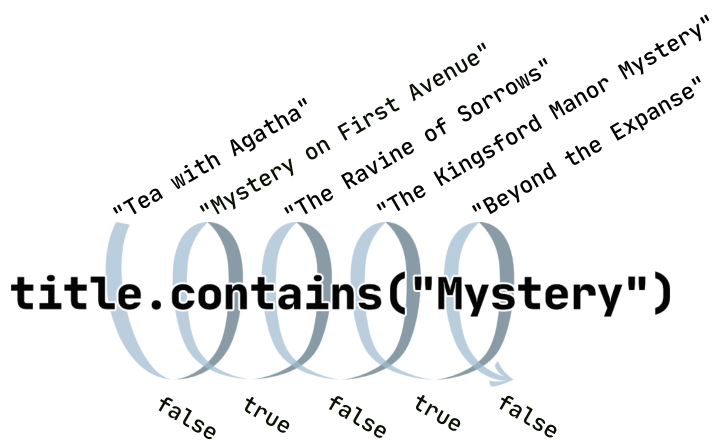
By using the **`contains()`** function inside the **`filter()`** lambda, we can filter the list of books down to only those that include the word "Mystery."

```kotlin
val booksForNolan = booksToRead
    .map { title -> title.removePrefix("The ") }
    .sorted()
    .filter { title -> title.contains("Mystery") }
```

*Listing 8.20 - Using the* **`filter()`** *function to filter out unwanted elements.*

The **`filter()`** function is similar to the **`map()`** function above—it takes a lambda as an argument, and that lambda will be invoked *once* for each title in the original list.

Unlike the **`map()`** function, however, the lambda for **`filter()`** must return a **`Boolean`**. If it returns **`true`** for an element, then that element is passed into the new collection (i.e., **`booksForNolan`** in this case). If it returns **`false`**, then it's omitted from the new collection.




Here's a breakdown of how to use the **`filter()`** function.


Printing each element of the list, here's what Libby saw.

```
Kingsford Manor Mystery
Mystery on First Avenue
```

"Great," she said. "The list is exactly like I wanted it. It includes only mysteries, and it's sorted properly!"

## Collection Operation Chains

Let's look at that code again.

```kotlin
val booksForNolan = booksToRead
    .map { title -> title.removePrefix("The ") }
    .sorted()
    .filter { title -> title.contains("Mystery") }
```

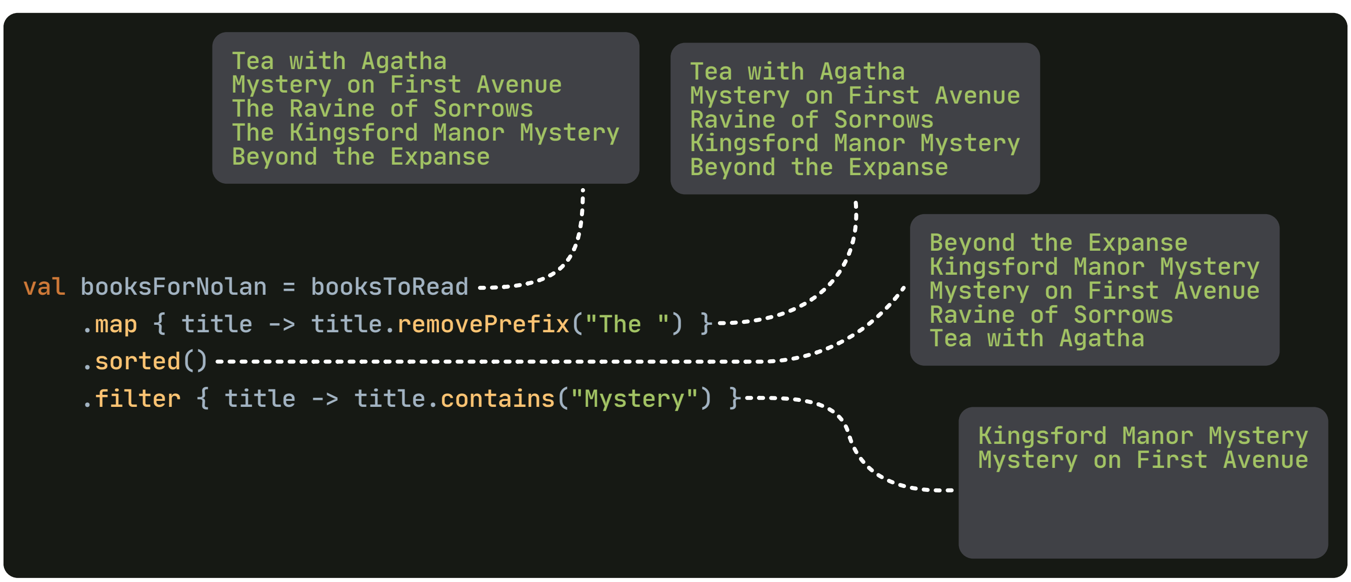
*Listing 8.21 - Using* `map()`*,* `sorted()`*, and* `filter()` *- copied from Listing 8.20.*

In Kotlin, it's common to put multiple collection operations together like this, one after another. When we do this, it's called **chaining** the collection operations—each operation is like one link in the chain. In this code listing, the `map()`, `sorted()`, and `filter()` calls are *chained* together.


Keep in mind that each operation in the chain *creates a new list* rather than mutating the original list. The list that's created by the *final* operation—in this case, `filter()`—is the list that is assigned to the `booksForNolan` variable.

The **intermediate lists**—that is, the lists that are created by the collection operations *inside* the chain—are used by the *next* operation in the chain, but are not assigned to any variable. It's still important to keep these intermediate lists in mind, though.

This next illustration shows the list that's involved at each step in the chain.



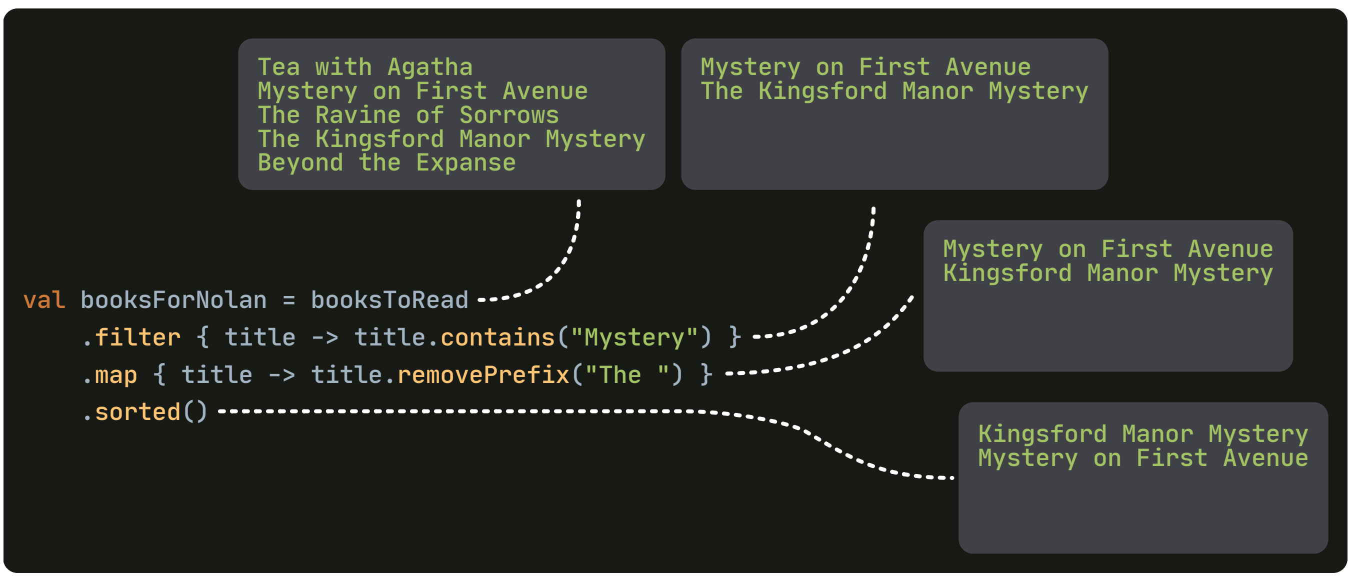
Whenever you've got a collection operation chain like this, it's helpful to consider how many elements are in each intermediate list. For example, the code in Listing 8.21 has the **`filter()`** call at the end of the chain. But what if it went at the *beginning* of the chain instead, like this?

```kotlin
val booksForNolan = booksToRead
    .filter { title -> title.contains("Mystery") }
    .map { title -> title.removePrefix("The ") }
    .sorted()
```

*Listing 8.22 - Moving the* **`filter()`** *call to the top of the chain.*

By doing this, the intermediate list that **`filter()`** produces would only have *two* elements, in which case the **`map()`** function would only need to invoke its lambda twice instead of five times, and **`sorted()`** would only have two items to sort instead of five. In this example, the final list is the same either way, but Listing 8.22 is likely to be more efficient than Listing 8.21.

Here's an illustration showing the list involved at each step when placing the **`filter()`** call at the top. Notice that the intermediate lists have fewer elements than they did in the previous illustration.




On a small list like this, it's not a big deal, but on a list that has hundreds or thousands of elements, it's easy to see how this could improve the **performance** of your code—in other words, it would run much faster!

## Other collection operations

Kotlin has many other collection operations that are easy to use! Just to give you an idea, here are a few others that can come in handy.

- **`drop(3)`** - The new list omits the first 3 elements from the original list.
- **`take(5)`** - The new list uses only the first 5 elements from the original list.

- **`distinct()`** - The new list will omit duplicate elements, so that each element is included only once.
- **`reversed()`** - The new list will have the same elements as the original, but their order will be backwards.

You can see a more complete list of them in the official Kotlin API documentation.

# Introduction to Sets

Before we wrap up this chapter, it's worth noting that lists aren't the only kind of collection in Kotlin.

Lists are probably the most frequently used, but another helpful collection type is called a **set**. Whereas a list ensures that its elements stay in a specific order, a set is ensures that *each element in it is always unique*.

For example, Nolan's favorite mystery author, Slim Chancery, has written three books, and Nolan is proud to say he's got the whole *set*.

Creating a set in Kotlin is just as easy as creating a list. Simply use **`setOf()`** or **`mutableSetOf()`** instead of **`listOf()`** or **`mutableListOf()`**.

```
val booksBySlim: Set<String> = setOf(
    "The Malt Shop Caper",
    "Who is Mrs. W?",
    "At Midnight or Later",
)
```

*Listing 8.23 - Creating a set of strings.*

If we add an element to a set that already has that value, the set will remain unchanged.

```
val booksBySlim: MutableSet<String> = mutableSetOf(
    "The Malt Shop Caper",
    "Who is Mrs. W?",
    "At Midnight or Later",
)

booksBySlim.add("The Malt Shop Caper")

println(booksBySlim)
// [The Malt Shop Caper, Who is Mrs. W?, At Midnight or Later]
```

*Listing 8.24 - Adding an element to a set that already contains that element. The set does not include it a second time.*

Note that a set *does not guarantee the order of its elements* when you print them out or use a collection operation on it. It's *possible* that the elements will be in the same order that you added them, but don't depend on it!

Because sets don't have any guaranteed order to their elements, their elements do not have indexes. For that reason, sets do not even include a **`get()`** function.

The key takeaway is that:

1. **`List`** objects have elements in a guaranteed order, and can contain duplicates.
2. **`Set`** objects have elements in no particular order, and are guaranteed not to contain duplicates.

Also, it's possible to convert a list into a set, or the other way around. Simply use **`toSet()`** or **`toList()`**, as shown below. Just remember that if you convert a list to a set, you'll lose duplicate elements, and the order could possibly be different!

```
val bookList = listOf(
    "The Malt Shop Caper",
    "At Midnight or Later",
    "The Malt Shop Caper",
)

val bookSet = bookList.toSet() // bookSet has two elements
val anotherBookList = bookSet.toList() // anotherBookList also has two elements
```

*Listing 8.25 - Converting between lists and sets.*

## Best Practice: Lists or Sets?

When deciding whether to use a list or a set, consider *how you intend to use the collection*. In the examples above, both the lists and the sets included book titles, but the deciding factor was *how the collection would be used*.

It made sense to use a list for the reading list, because Libby wants to read the books in a particular order, and it's possible that she might want to read the same book more than once.

For the books by Slim Chancery, a set made sense because the order didn't matter, but we wanted to make sure there were no duplicates in it—Slim loves writing a good mystery, but he never writes the same book twice!

However, if we wanted his books ordered by title or publication date, a list would be more appropriate.

# Summary

Thanks to Kotlin's collection types, Libby can keep her reading lists organized and share them with her friends. By using lists, she can keep the books in order, and with sets, she can avoid duplicates. Now she's ready to crack open the first book and get immersed in the story!

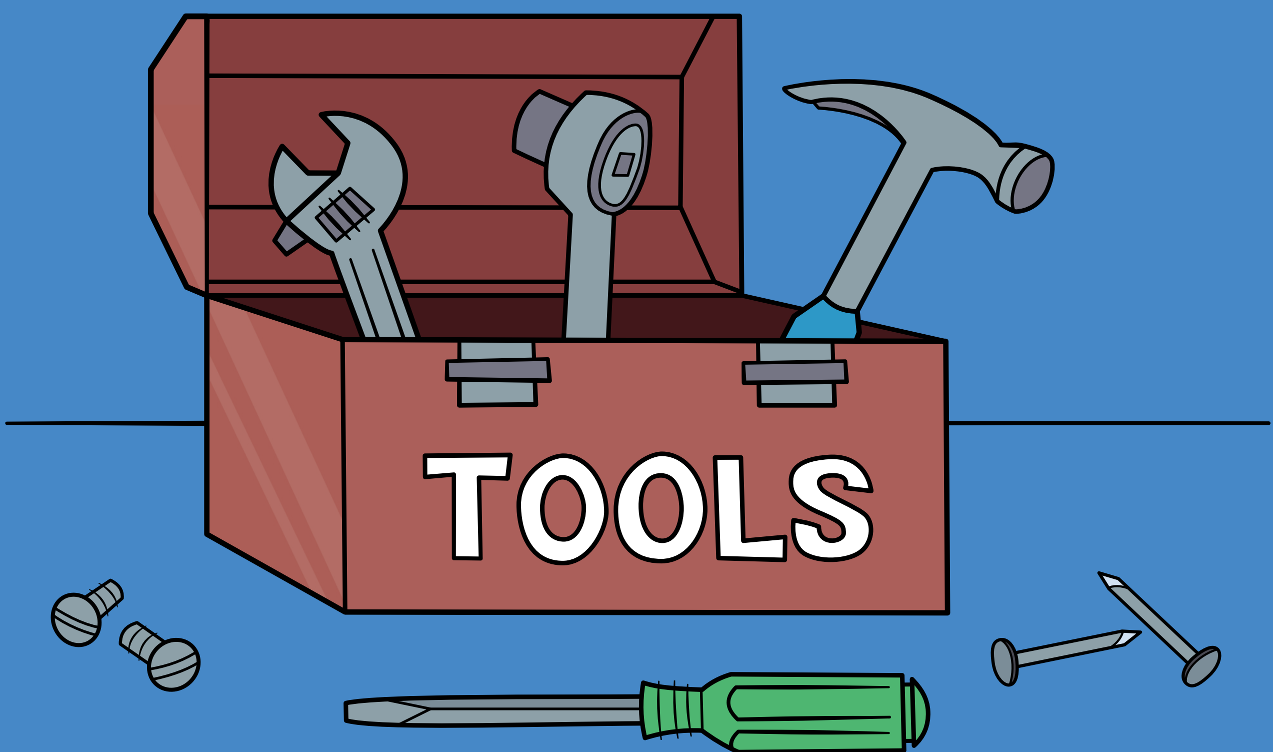
Up until this chapter, we've only worked with individual variables. By using collections like lists and sets, we're able to do things with entire groups of values, which opens a whole new world of possibilities! In this chapter, you learned about collections, including:

- How to create a list.
- How to create lists by adding or removing an element from another list.
- The difference between immutable and mutable collections.
- How to get a single element out of a list.
- Collection operations, like **`filter()`**, **`map()`**, and **`sorted()`**.
- The difference between a list and a set.

We discovered how easy it is to get an element from a list by its index. However, sometimes we want an easy way to get an element by *some other information* about it. For example, instead of getting a book by its positional index, we might want to get a book by its ISBN (that long number above the barcode on the back). In the next chapter, we'll learn about another way to group elements that will make it easy to do this!

Kotlin: An Illustrated Guide
Chapter 9

# Collections: Maps



## Let’s associate data and group values together.

In the last chapter, we saw how collections, such as lists and sets, can be used to do things that couldn’t be done easily with separate, individual variables.

In this chapter, we’re going to look at another kind of collection—a map, which can hold many associations between values.

Let’s check it out!

# The Right Tool for the Job

"You gotta use the right tool for the job." That's what Mr. Patchwell taught his young son, Jack, who was just starting to learn how to become a handyman like his old man. "When you've got a nail, you need to use a hammer, not a screwdriver."

In order to help Jack pick out the right tool, he sketched out a table of the different hardware and tools in his toolbox.

| Hardware | Tool to Use |
|---|---|
| Nail | Hammer |
| Hex Nut | Wrench |
| Hex Bolt | Wrench |
| Slotted Screw | Slotted Screwdriver |
| Phillips Screw | Phillips Screwdriver |

"Now, with this table, you can easily look up what tool you need. Just scan down the left-hand column for the hardware you need to work with, and then scan across to see the right tool to use."

Which tool should be used with a Slotted Screw?

| Hardware | Tool to Use |
|---|---|
| Nail | Hammer |
| Hex Nut | Wrench |
| Hex Bolt | Wrench |
| Slotted Screw | Slotted Screwdriver |
| Phillips Screw | Phillips Screwdriver |

A Slotted Screwdriver!

Tables like this show that there are **associations** between things—a nail is associated with a hammer, a hex nut is associated with a wrench, and so on. In this chapter, we'll build out Kotlin's equivalent of a table like this, but before we do, let's start by creating a single association.

# Associating Data

One simple way to associate two values is to use a class called `Pair`. The constructor of this class has two parameters. You can call its constructor with *any* two objects, regardless of their types. In our case, let's associate two `String` objects—one for a nail, and one for a hammer.

```kotlin
val association = Pair("Nail", "Hammer")
```

*Listing 9.1 - Creating a simple association with the* **`Pair`** *class.*

**`Pair`** is a very simple class that has two properties, **`first`** and **`second`**, which you can use to get the values back out of it.

To the right is a UML diagram showing the **`Pair`** class. The types of **`first`** and **`second`** depend on the types of the arguments you give it when calling its constructor, so in this diagram, we will just use **`A`** and **`B`** as placeholders for the actual types.

| Pair<A,B> |
|---|
| + first: A<br>+ second: B |

The **`first`** property will be whatever the *first* argument was when you called the constructor, and the **`second`** will be whatever the *second* argument was.

```kotlin
println(association.first)  // Nail
println(association.second) // Hammer
```

*Listing 9.2 - Printing the* **`first`** *and* **`second`** *properties of the* **`Pair`**.

Now, instead of calling the constructor of the **`Pair`** class, it's sometimes more natural to use a function named **`to()`**, which will call the **`Pair`** constructor for you. This function can be called on *any object at all*. Let's update our code so that it uses the **`to()`** function.

```kotlin
val association = "Nail".to("Hammer")
```

*Listing 9.3 - Creating a* **`Pair`** *with the* **`to`** *function.*

When reading this code, we could say, "When I have a **`Nail`**, then I should go **`to`** a **`Hammer`**." Both Listing 9.1 and Listing 9.3 do the same thing—they create a **`Pair`** where the left-hand value is assigned to the property named **`first`** and the right-hand value is assigned to the property named **`second`**.

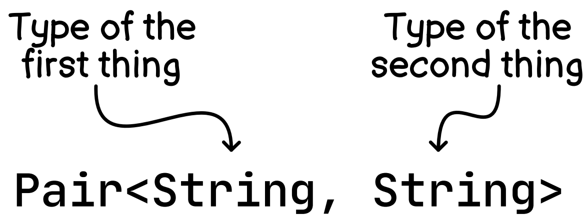
The **`to()`** function also has a special characteristic about it that lets us use it without the punctuation! So, we can also create this same **`Pair`** like this.

```kotlin
val association = "Nail" to "Hammer"
```

*Listing 9.4 - Creating a* **`Pair`** *with the* **`to`** *function, without the punctuation.*

Notice that this is the same as Listing 9.3 above, except that the dot and both parentheses are missing. When a function can be called this way, it's known as an **infix function**. We won't see infix functions often, but it's important to know that they exist so that they won't confuse you when you see code like this.

So far, we've used type inference so that we don't have to write out the type of the **`association`** variable. As with **`List`** and **`Set`** in the previous chapter, the type of a **`Pair`** variable depends on the type of the things that it contains. Since both `"Nail"` and `"Hammer"` have type `String`, the type of the `association` variable is `Pair<String, String>`.




And of course, we can specify the type explicitly like this.

```kotlin
val association: Pair<String, String> = "Nail" to "Hammer"
```

*Listing 9.5 - Explicitly specifying the type of the* `association` *variable.*

Now that we've successfully made a single association, we can do the same thing for the rest of the tools… and then put them all together into a map!

# Map Fundamentals

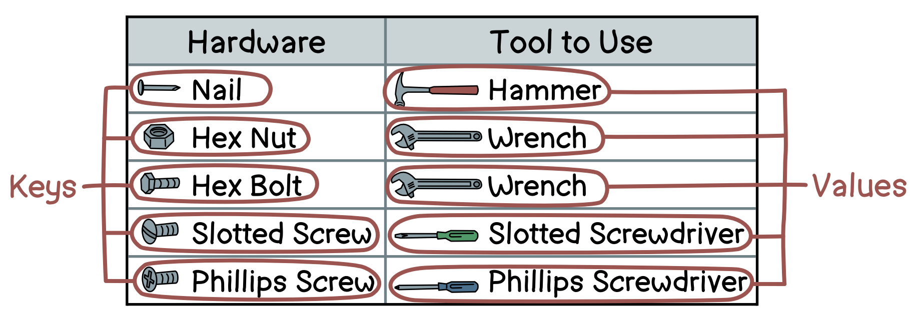
Let's look at Mr. Patchwell's table again.

| Hardware | Tool to Use |
|---|---|
| Nail | Hammer |
| Hex Nut | Wrench |
| Hex Bolt | Wrench |
| Slotted Screw | Slotted Screwdriver |
| Phillips Screw | Phillips Screwdriver |

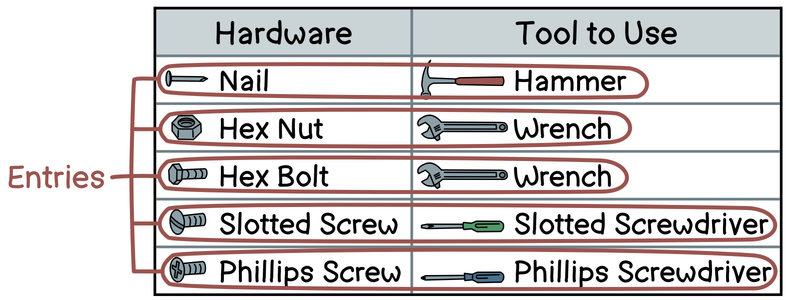
In Kotlin, a table like this is called a **map**. This might bring to mind maps like street maps and treasure maps, but that's not what we're talking about here.

The term comes from the world of mathematics, where a map defines a *correspondence* between elements of sets. Similarly, Kotlin maps define an association between each item in the left-hand column, and its corresponding item in the right-hand column.

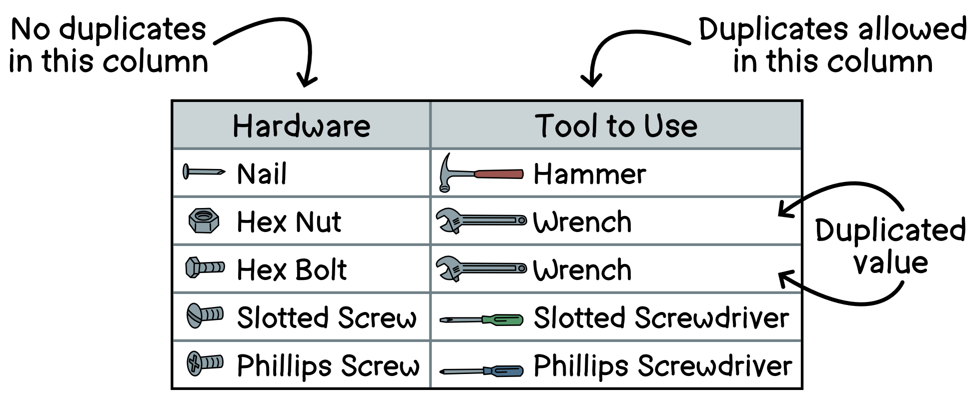
Before we create our first map, let's cover a few important terms. The items in the left-hand column of the table are called **keys** and the items in the right-hand column are called **values**.




The association of a key and a value within a map is called a map **entry**.




There's an important rule to keep in mind—each *key* in a map is unique. However, the *values* can be duplicated. In other words, we cannot have duplicate items in the left-hand column, but it's fine in the right-hand column. In the table below, notice that the left-hand column items are unique, but the wrench appears twice in the right-hand column.




## Creating a Map with mapOf()

Now that we understand the main concepts, it's time to create our first map! To do this, we'll use the **`mapOf()`** function, passing in a **`Pair`** for each association that we want in the map.

```kotlin
val toolbox = mapOf(
    "Nail" to "Hammer",
    "Hex Nut" to "Wrench",
    "Hex Bolt" to "Wrench",
    "Slotted Screw" to "Slotted Screwdriver",
    "Phillips Screw" to "Phillips Screwdriver",
)
```

*Listing 9.6 - Creating a map.*

The **`mapOf()`** function looks similar to **`listOf()`** and **`setOf()`** that we saw in the last chapter, except that all of the elements here have two pieces—the *key* and the *value*—which are joined together in a **`Pair`**.

## By the Way: `to()` and `Pair`

Remember—**`to()`** is just a convenient way to create a **`Pair`**. We could have created the map like this.

```
val toolbox = mapOf(
    Pair("Nail", "Hammer"),
    Pair("Hex Nut", "Wrench"),
    // ... and so on ...
)
```

We can see the similarities between the Kotlin map and Mr. Patchwell's table when we place them side by side.

```
val toolbox = mapOf(
  "Nail" to "Hammer",
  "Hex Nut" to "Wrench",
  "Hex Bolt" to "Wrench",
  "Slotted Screw" to "Slotted Screwdriver",
  "Phillips Screw" to "Phillips Screwdriver"
)
```

| Hardware | Tool to Use |
|---|---|
| Nail | Hammer |
| Hex Nut | Wrench |
| Hex Bolt | Wrench |
| Slotted Screw | Slotted Screwdriver |
| Phillips Screw | Phillips Screwdriver |

Just as with lists, sets, and other objects, we can use **`println()`** to print out the contents of a map.

```
println(toolbox)
```

*Listing 9.7 - Code to print the contents of a map to the screen.*

When we print this out, the entries of the map appear between braces. The keys are to the left of the equal signs, and the values are to the right.

```
{Nail=Hammer, Hex Nut=Wrench, Hex Bolt=Wrench, Slotted Screw=Slotted Screwdriver,
Phillips Screw=Phillips Screwdriver}
```

Just like with **`Pair`**, the type of a **`Map`** variable depends on the type of the key and the type of the value.

Type of the key

Type of the value

```
Map<String, String>
```

So, we could write out the type explicitly like this.

```
val toolbox: Map<String, String> = mapOf(
    "Nail" to "Hammer",
    "Hex Nut" to "Wrench",
    "Hex Bolt" to "Wrench",
    "Slotted Screw" to "Slotted Screwdriver",
    "Phillips Screw" to "Phillips Screwdriver",
)
```

*Listing 9.8 - Explicitly specifying the type of the* `toolbox` *variable.*

## Looking Up a Value

The most common thing that we'll need to do with a map is to look up a value. When Jack has a nail, for example, he needs to look up which tool to use. Just as Jack would find the nail in the left-hand column and find the corresponding tool next to it, Kotlin can give us a value when we provide it a key. We can use the `get()` function to do this.

```
val tool = toolbox.get("Nail")
println(tool) // Hammer
```

*Listing 9.9 - Getting a value from a map by the value's corresponding key.*

Similar to lists, we can also use the indexed access operator with maps to get a value.

```
val tool = toolbox["Nail"]
println(tool) // Hammer
```

*Listing 9.10 - Using the indexed access operator to get a value from a map.*

If we call `get()` (or use the indexed access operator) with a key that does not exist in the map, it will return a `null`. This means the `get()` function returns a nullable type rather than a non-nullable type! In Listing 9.9 and 9.10, it returns a `String?` rather than a `String`. We can use the null-safety tools that we learned about in Chapter 6 (such as the elvis operator) to get it back to a non-nullable type.

Alternatively, we can call `getValue()` instead of `get()`. `getValue()` will return a non-nullable type, but be warned—if you give it a key that does not exist, you'll see an error message and your code will stop running.

```
val tool = toolbox.getValue("Nail")
println(tool) // Hammer

val anotherTool = toolbox.getValue("Wing Nut") // Error at runtime
```

*Listing 9.11 - Using the* `getValue()` *function to get a value with a non-nullable type.*

We can also use **`getOrDefault()`** to provide a default value if the key doesn't exist. If Mr. Patchwell doesn't have a tool for a particular piece of hardware, he'll just need to tighten it by hand!

```
val tool = toolbox.getOrDefault("Hanger Bolt", "Hand")
```

*Listing 9.12 - Using* **`getOrDefault()`** *to provide a default value if the key does not exist in the map.*

## Modifying a Map

As with the other collection types, maps come in two flavors of mutability—**`MutableMap`** and an *immutable* **`Map`**. The mutable variety allows us to change its contents, whereas an immutable map requires us to create a *new* map instance that you can assign to a new or existing variable.

Let's look at how to change a **`MutableMap`** first. To start with, we'll need to use **`mutableMapOf()`** to create the map, instead of just **`mapOf()`**, which we used back in Listing 9.6.

```
val toolbox = mutableMapOf(
    "Nail" to "Hammer",
    "Hex Nut" to "Wrench",
    "Hex Bolt" to "Wrench",
    "Slotted Screw" to "Slotted Screwdriver",
    "Phillips Screw" to "Phillips Screwdriver",
)
```

*Listing 9.13 - Creating a mutable map.*

To add a new entry, we can use the **`put()`** function, where the first argument is the key, and the second argument is the value.

```
toolbox.put("Lumber", "Saw")
```

*Listing 9.14 - Adding a new entry to a mutable map using the* **`put()`** *function.*

Just like with the **`get()`** function, though, Kotlin developers typically use the *indexed access operator* instead of calling the **`put()`** function directly. The following code accomplishes the same thing as Listing 9.14.

```
toolbox["Lumber"] = "Saw"
```

*Listing 9.15 - Adding a new entry to a mutable map using the indexed access operator.*

It's also possible to *change an existing value* exactly the same way. Just provide a key that already exists.

```
toolbox["Hex Bolt"] = "Nut Driver"
```

*Listing 9.16 - Changing an existing value in a mutable map.*

Finally, we can remove an entry using the `remove()` function.

```
toolbox.remove("Lumber")
```

*Listing 9.17 - Removing an entry from a map.*

Note that although we can change a value, we *cannot change a key*. Instead, we have to remove a key and insert a new entry.

```
toolbox.remove("Phillips Screw")
toolbox["Cross Recess Screw"] = "Phillips Screwdriver"
```

*Listing 9.18 - Removing an entry and reinserting it with a new key, to simulate changing a key.*

## Immutable Maps

As with immutable lists and sets, we can use the *plus* and *minus operators* on an immutable map. Remember, doing so will create *new map instances*, which would then typically be assigned to a variable.

The following code demonstrates the same operations as we did above, but on an immutable map.

```
var toolbox = mapOf(
    "Nail" to "Hammer",
    "Hex Nut" to "Wrench",
    "Hex Bolt" to "Wrench",
    "Slotted Screw" to "Slotted Screwdriver",
    "Phillips Screw" to "Phillips Screwdriver",
)

// Add an entry
toolbox = toolbox + Pair("Lumber", "Saw")

// Update an entry
toolbox = toolbox + Pair("Hex Bolt", "Nut Driver")

// Remove an entry
toolbox = toolbox - "Lumber"

// Simulate changing a key
toolbox = toolbox - "Phillips Screw"
toolbox = toolbox + Pair("Cross Recess Screw", "Phillips Screwdriver")
```

*Listing 9.19 - Adding, changing, and removing entries by replacing an immutable map.*

Notice that we used the `var` keyword here so that we could assign each result back to the same `toolbox` variable.

## Map Operations

As with **`List`** and **`Set`**, **`Map`** objects have operations that can be performed on them, and some of them will look very familiar! Let's start with the **`forEach()`** function.

### forEach()

The **`forEach()`** function is almost identical to the one found on **`List`** and **`Set`** objects. It takes a lambda that we can use to do something with each entry in the map. Since maps store *entries*, the parameter of the lambda will be of type **`Map.Entry`**.[1]

```
Map.Entry<K,V>
+ key: K
+ value: V
```

**`Map.Entry`** is very similar to the **`Pair`** class that we looked at earlier in this chapter—it has two properties on it, but instead of being named **`first`** and **`second`**, they're named **`key`** and **`value`**.

Here's how we can use the **`forEach()`** function on a **`Map`**.

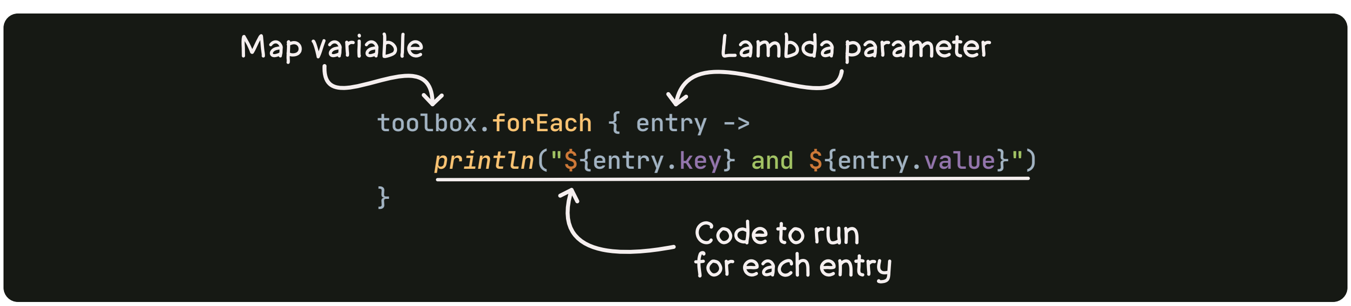
```
toolbox.forEach { entry ->
    println("Use a ${entry.value} on a ${entry.key}")
}
```

*Listing 9.20 - Using the* **`forEach()`** *function on a map.*

When we run this code, here's what we'll see.

```
Use a Hammer on a Nail
Use a Wrench on a Hex Nut
Use a Wrench on a Hex Bolt
Use a Slotted Screwdriver on a Slotted Screw
Use a Phillips Screwdriver on a Phillips Screw
```

Because it's so similar to the **`forEach()`** function that we saw in the last chapter, it should be easy to identify the main parts. Here they are.




[1] This type has a dot in the name because it's a type that's defined *within* another type - **`Entry`** is defined within the **`Map`** type.

## Filtering

Similar to lists and sets, we can **`filter`** a map.

Keep in mind that, just as we saw with lists, this function doesn't modify an existing map—it creates a new map instance, so you'll probably want to assign the result to a variable. Let's filter down the toolbox to just screwdrivers.

```kotlin
val screwdrivers = toolbox.filter { entry ->
    entry.value.contains("Screwdriver")
}
```

*Listing 9.21 - Using the* **`filter()`** *function on a map.*

The result is a new **`Map`** that contains only the screwdrivers.

| Hardware | Tool to Use |
|---|---|
| Nail | Hammer |
| Hex Nut | Wrench |
| Hex Bolt | Wrench |
| Slotted Screw | Slotted Screwdriver |
| Phillips Screw | Phillips Screwdriver |

| Hardware | Tool to Use |
|---|---|
| Slotted Screw | Slotted Screwdriver |
| Phillips Screw | Phillips Screwdriver |

In this case, we filtered on the **`value`**, but it's just as easy to filter by the keys.

```kotlin
val screwdrivers = toolbox.filter { entry ->
    entry.key.contains("Screw")
}
```

*Listing 9.22 - Filtering a map based on the entry's key.*

## Mapping

Yes, we can map a **`Map`**! Simply use the **`mapKeys()`** and **`mapValues()`** functions to convert its keys or values. Just like with the collection operations we looked at in the last chapter, it's possible to create an [operation chain](). Let's map both keys and values in one chain.

```kotlin
val newToolbox = toolbox
  .mapKeys { entry -> entry.key.replace("Hex", "Flange") }
  .mapValues { entry -> entry.value.replace("Wrench", "Ratchet") }
```

*Listing 9.23 - Mapping both keys and values of a map.*

| Hardware | Tool to Use |
|---|---|
| Nail | Hammer |
| Hex Nut | Wrench |
| Hex Bolt | Wrench |
| Slotted Screw | Slotted Screwdriver |
| Phillips Screw | Phillips Screwdriver |

| Hardware | Tool to Use |
|---|---|
| Nail | Hammer |
| Flange Nut | Ratchet |
| Flange Bolt | Ratchet |
| Slotted Screw | Slotted Screwdriver |
| Phillips Screw | Phillips Screwdriver |

`Map` objects have many other operations on them, which you can explore in Kotlin's API docs. However, there's one more operation that we'll examine before continuing—`withDefault()`.

## Setting Default Values

As we saw earlier, we can use `getOrDefault()` to gracefully handle cases where the key does not exist. However, this can quickly get out of control if we use the same default every time!

```
val tool = toolbox.getOrDefault("Hanger Bolt", "Hand")
val another = toolbox.getOrDefault("Dowel Screw", "Hand")
val oneMore = toolbox.getOrDefault("Eye Bolt", "Hand")
```

*Listing 9.24 - Using `getOrDefault()` can get out of hand when used at every call site.*

Instead, we can use an operation named `withDefault()`, which will return a new map based on the original. In this new map, whenever we call `getValue()` with a key that doesn't exist, it will invoke a lambda and return the result. Here's how it looks.

```
toolbox = toolbox.withDefault { key -> "Hand" }
```

*Listing 9.25 - Creating a new map that has a default value.*

Now, instead of providing the default every time we try to get a value (as done in Listing 9.24 above), we can just call `getValue()` normally.

This is great, because if we ever want to change the default, we can make the change in one spot instead of many!

```
val tool = toolbox.getValue("Hanger Bolt")
val another = toolbox.getValue("Dowel Screw")
val oneMore = toolbox.getValue("Eye Bolt")
```

*Listing 9.26 - Calling `getValue()` instead of `getOrDefault()`, because the new map has a default value.*

Keep in mind that this works with `getValue()` but *not* with `get()` or the indexed access operator, which will continue to return `null` if the key is not found!

Now you know how to create and change maps, get values out of them, and use collection operations on them. But things get really fun when maps are used in conjunction with other *collections*! Let's look at that next.

# Creating a Map from a List

We've created maps by hand using the **mapOf()** function. It's also possible to create maps that are based on *existing list or set collections*. With just a few important functions, we can slice and dice our data in many different ways! In order to do this, of course, we will need a list to start with.

Instead of using a simple **String** to represent the tools in Mr. Patchwell's toolbox, let's create a class, so that it can hold the name of the tool, its weight in ounces, and the corresponding hardware that it works with.

```
class Tool(
    val name: String,
    val weightInOunces: Int,
    val hardware: String,
)
```

*Listing 9.27 - Creating a class to hold more information about a tool.*

Now, let's create a list of **Tool** objects, so that they include the tools from Mr. Patchwell's toolbox.

```
val tools = listOf(
    Tool("Hammer", 14, "Nail"),
    Tool("Wrench", 8, "Hex Nut"),
    Tool("Wrench", 8, "Hex Bolt"),
    Tool("Slotted Screwdriver", 5, "Slotted Screw"),
    Tool("Phillips Screwdriver", 5, "Phillips Screw"),
)
```

*Listing 9.28 - Creating a list of tools.*

Now that we have a list, we're ready to create some maps from it!

## Associating Properties from a List of Objects

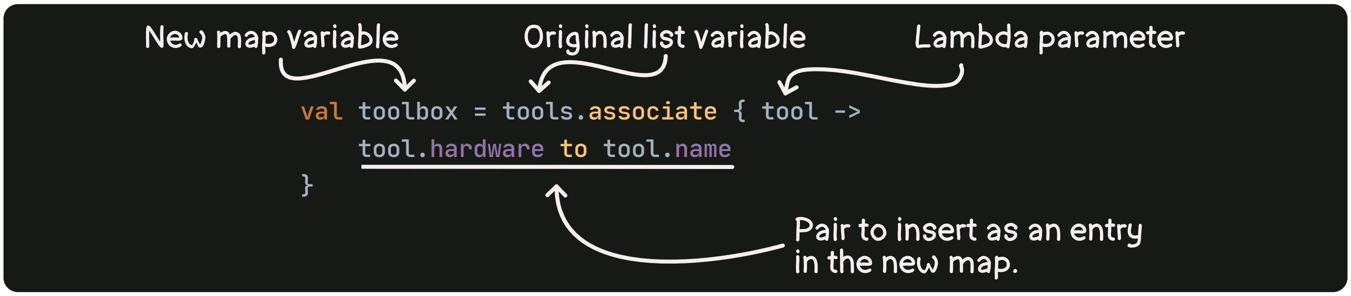
We can use the **associate()** function to create a map from a list of objects. To start with, let's use **associate()** to create a map similar to the one in Listing 9.6.

```
val toolbox = tools.associate { tool ->
    tool.hardware to tool.name
}
```

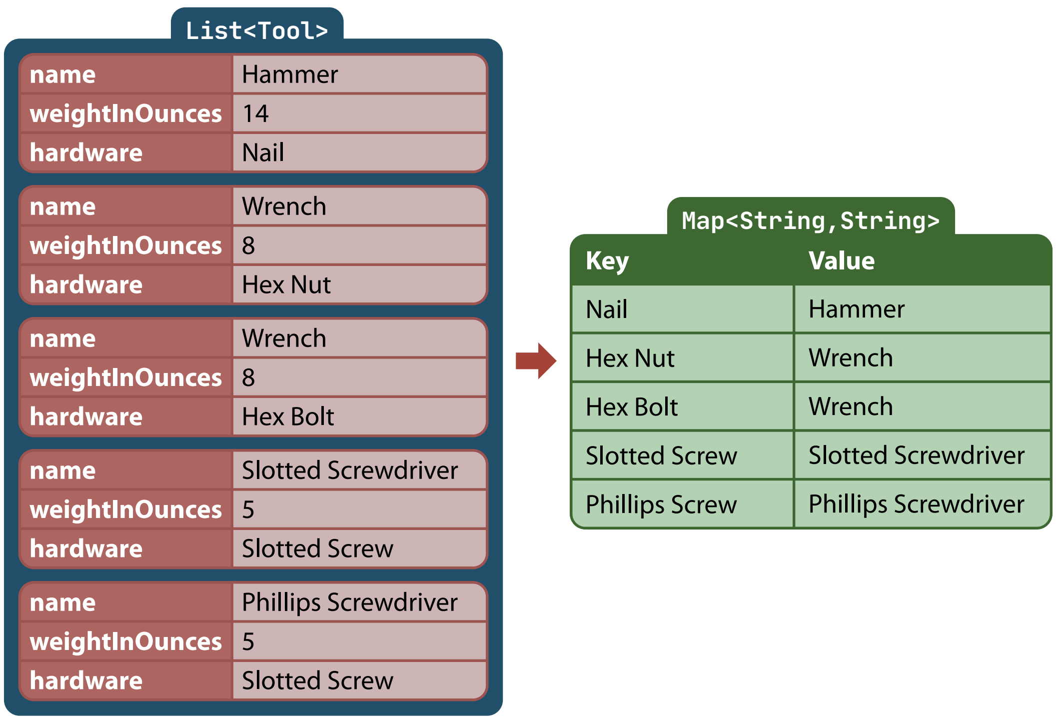
*Listing 9.29 - Creating a map by associating two properties in the elements of a list.*

Hopefully you're starting to feel more comfortable with collection operations at this point. For each element in the list, the `associate()` function will invoke the lambda given to it. The lambda returns a key-value `Pair`, which contains the key and value that should be included in the resulting map.

Here's a breakdown of the `associate()` function.




And here's the effect that it has in Listing 9.29.




Often, the number of elements in the resulting map will be the same as the number of elements in the original list. In some cases, it could have fewer. Because the keys in a map are all unique, if we try to add a key that already exists, it will *overwrite* the existing value.

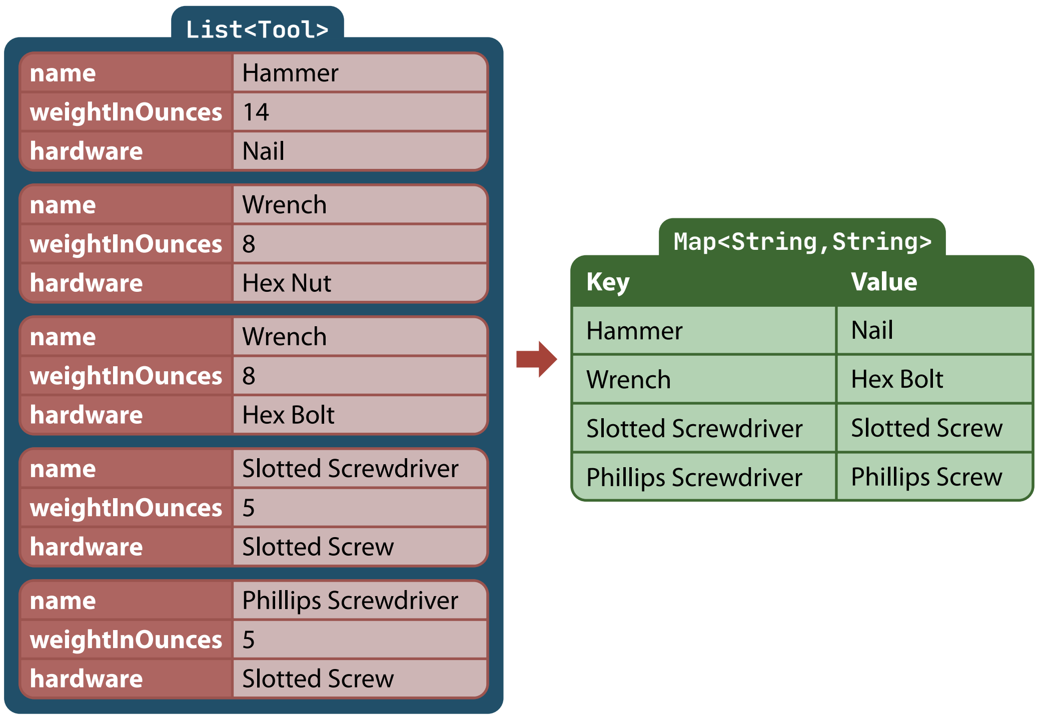
For example, let's reverse the key and value in the lambda in Listing 9.29, so that the tool `name` is the key, and the `hardware` is the value.

```
val toolbox = tools.associate { tool ->
    tool.name to tool.hardware
}
```

*Listing 9.30 - Associating the properties in the reverse order from Listing 9.29.*

The original list has two **`Tool`** objects with a **`name`** of **`"Wrench"`**, so when **`associate()`** encounters the *first* one, it's added to the map, but when it encounters the *second*, it replaces the first value.

So, the resulting map only includes **`"Hex Bolt"`** rather than **`"Hex Nut"`**, because of the two, **`"Hex Bolt"`** came last.




So in this case, there are fewer entries in the map than elements in the original list. That is, there are only 4 entries in the map, compared with 5 elements in the list.

## Other Association Functions

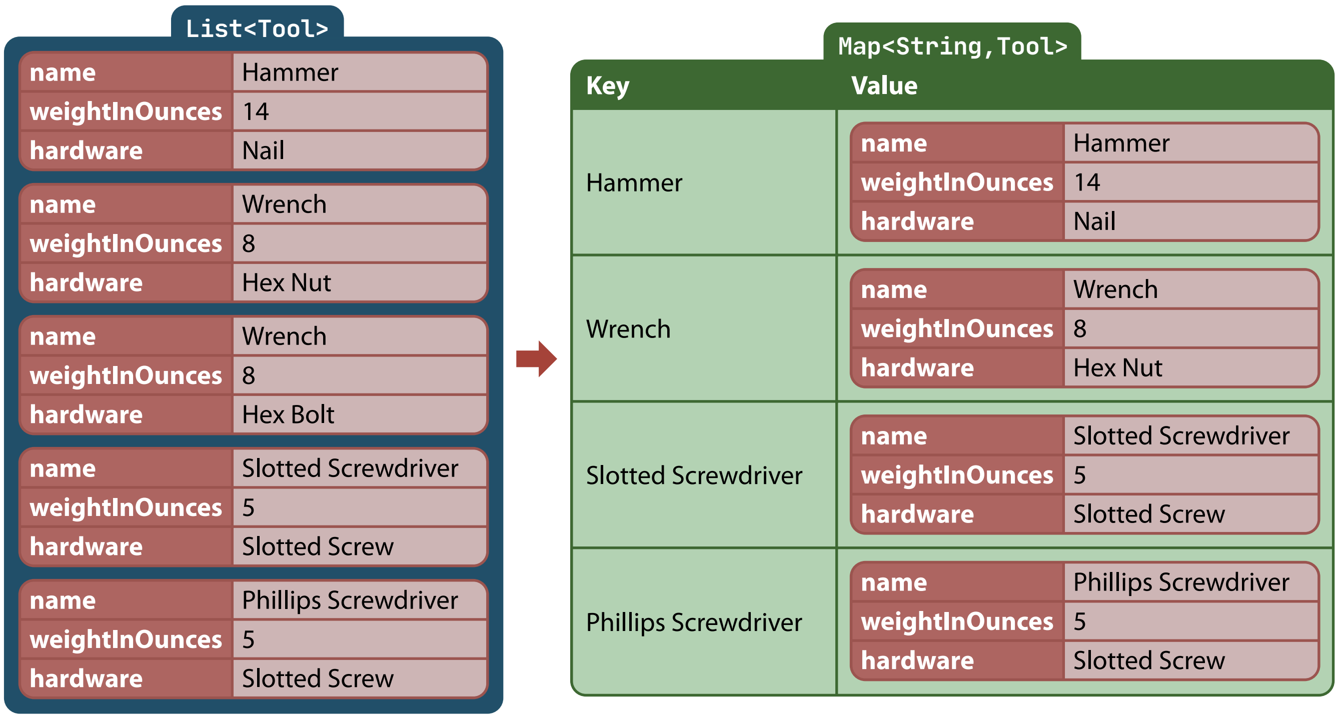
There are a few other variations of the **`associate()`** function that are good to know. These are especially helpful when we want the original list element to be either the *key* or the *value* in the resulting map.

For example, if we want to create a map where the keys are the tool names and the value is the **`Tool`** object, we can use **`associateBy()`**. The lambda of this function returns just the *key*. The original list element itself will be the value.

```
val toolsByName = tools.associateBy { tool -> tool.name }
```

*Listing 9.31 - Calling* **`associateBy()`** *to create a map where the original list elements are the map's values.*

The effect of this function is shown in the following illustration.




With this map, we can easily get a tool by its name!

```
val hammer = toolsByName["Hammer"]
```

*Listing 9.32 - Getting a* **`Tool`** *from a map by its name.*

Inversely, when we want to create a map where the keys are the **`Tool`** object and the value is specified in the lambda, we can use the **`associateWith()`** function. The lambda of this function returns the *value*, and the original list element will be the key.

```
val toolWeightInPounds = tools.associateWith { tool ->
    tool.weightInOunces * 0.0625
}
```

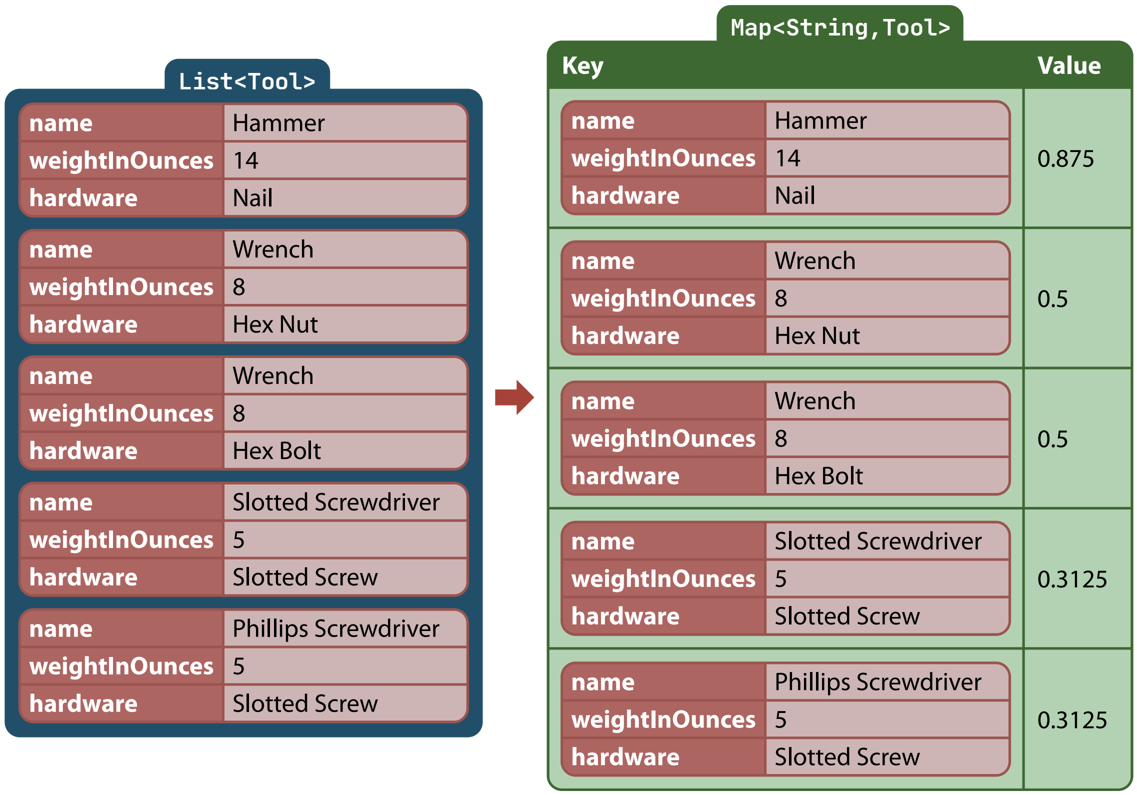
*Listing 9.33 - Calling* **`associateWith()`** *to create a map where the original list elements are the map's keys.*

## Technically Speaking: `associateBy()`

The **`associateBy()`** function also has a version that accepts *two* arguments—one lambda that returns the key, and one lambda that returns the value. It accomplishes the same thing as the regular **`associate()`** function, but it can sometimes run faster on large lists because it doesn't create a temporary **`Pair`** object for each element like **`associate()`** does.

Here's how we could use it to create the same map as in Listing 9.29:

```
val toolbox = tools.associateBy({ it.hardware }, { it.name })
```

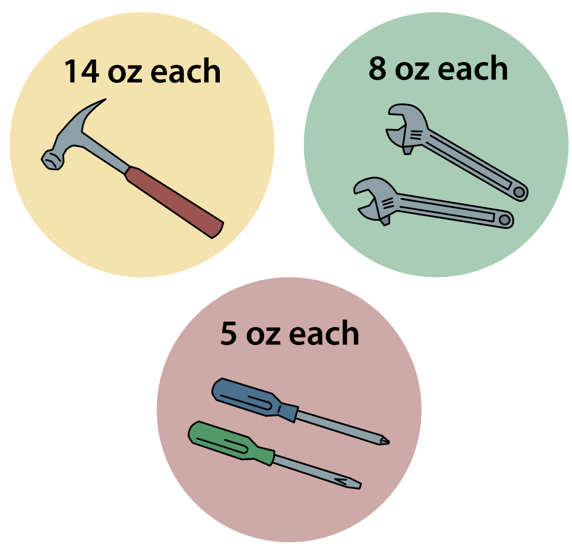



To get the weight of a hammer, we'd need to have a hammer object already.

```
val hammerWeightInPounds = toolWeightInPounds[hammer]
```

*Listing 9.34 - Using an object as a key.*

## Grouping List Elements into a Map of Lists




Sometimes when you've got a list, you want to split it up into multiple smaller lists, based on some characteristic. For example, we can take the **`tools`** list and split it up by weight.

To do this, we can use the **`groupBy()`** function. This function will run the provided lambda for each element in the list.

Elements for which the lambda returns the same result will be assembled into a list, and inserted into a map.

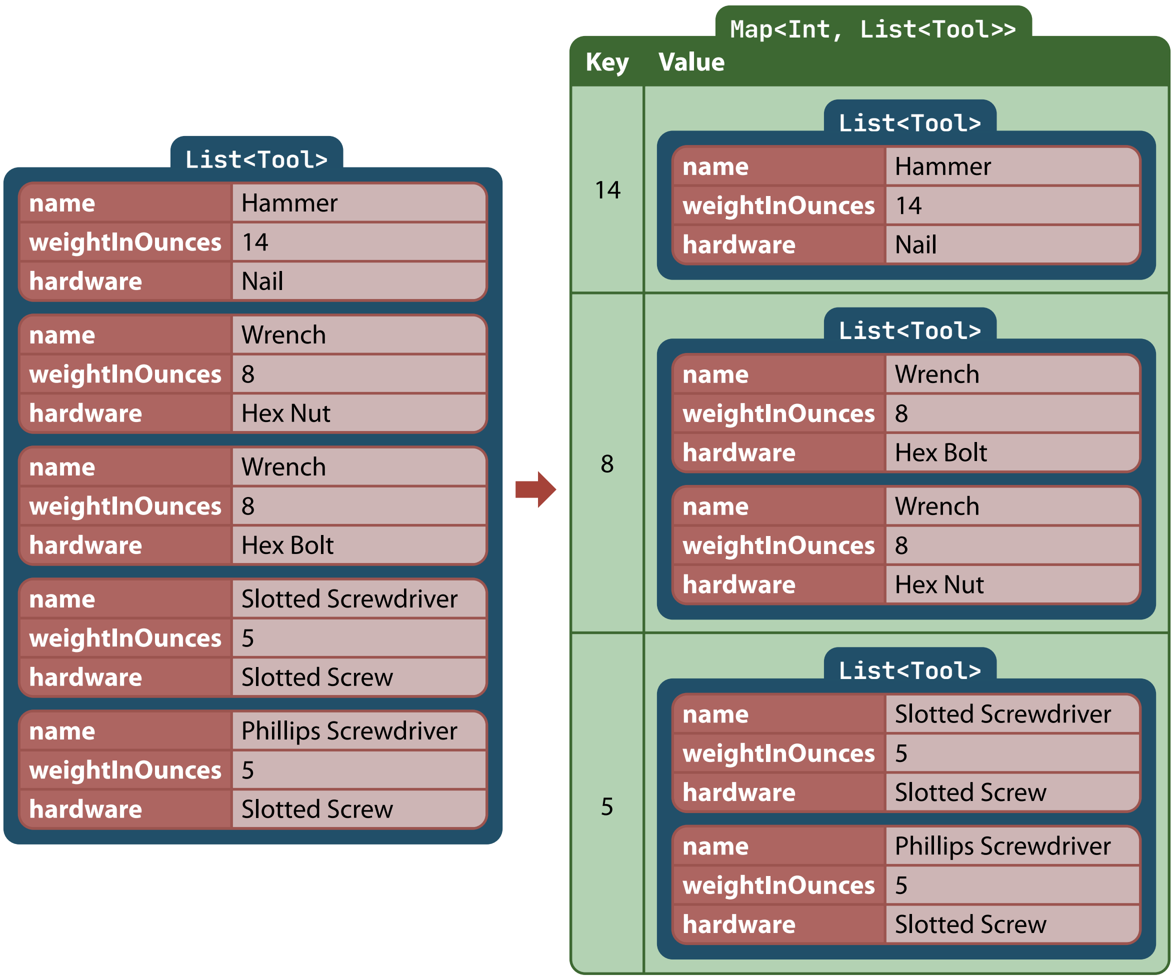
```
val toolsByWeight = tools.groupBy { tool ->
    tool.weightInOunces
}
```

*Listing 9.35 - Using the **`groupBy()`** function to group a list of tools by their weight.*

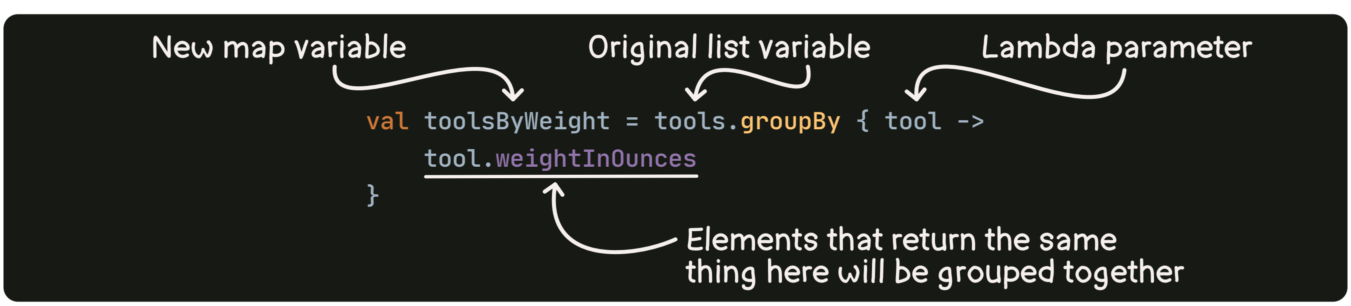
The result is a `Map` with one list of tools that weigh 14 ounces, *another* list of tools that weigh 8 ounces, and a *third* list of tools that weigh 5 ounces.

The map's *key* is the weight in ounces, and the map's *value* is a list of tools that have that weight.

This illustration shows the effect that this operation has.




Here's a breakdown of the `groupBy()` function.

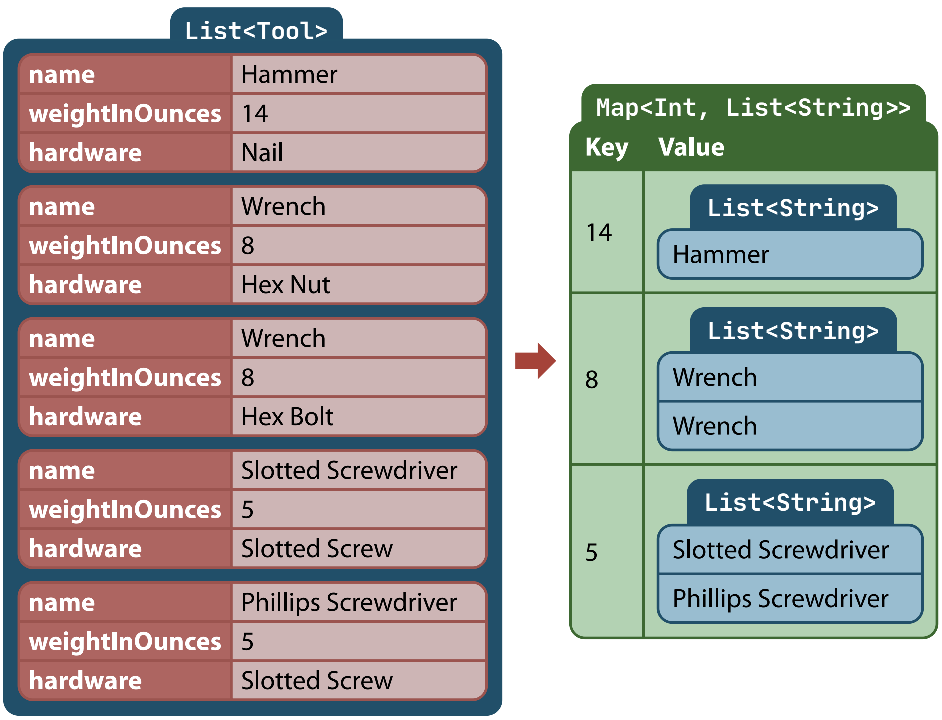



When we want something *other* than the original list element in the resulting lists, we can also call this function with a *second* argument. For that one, we can just give it a lambda that returns whatever we want in the resulting list. For example, if we only want the *names* of the tools in those lists, we can do this.

```kotlin
val toolNamesByWeight = tools.groupBy(
    { tool -> tool.weightInOunces },
    { tool -> tool.name }
)
```

*Listing 9.36 - Calling the* **`groupBy()`** *function with two arguments instead of one.*

Here's the effect that this operation has.




# Summary

Jack is well on his way to becoming a great handyman like his father, and with maps in your programming toolbox, you're ready to bolt together some key-value pairs like a pro!

Here's what you learned in this chapter:

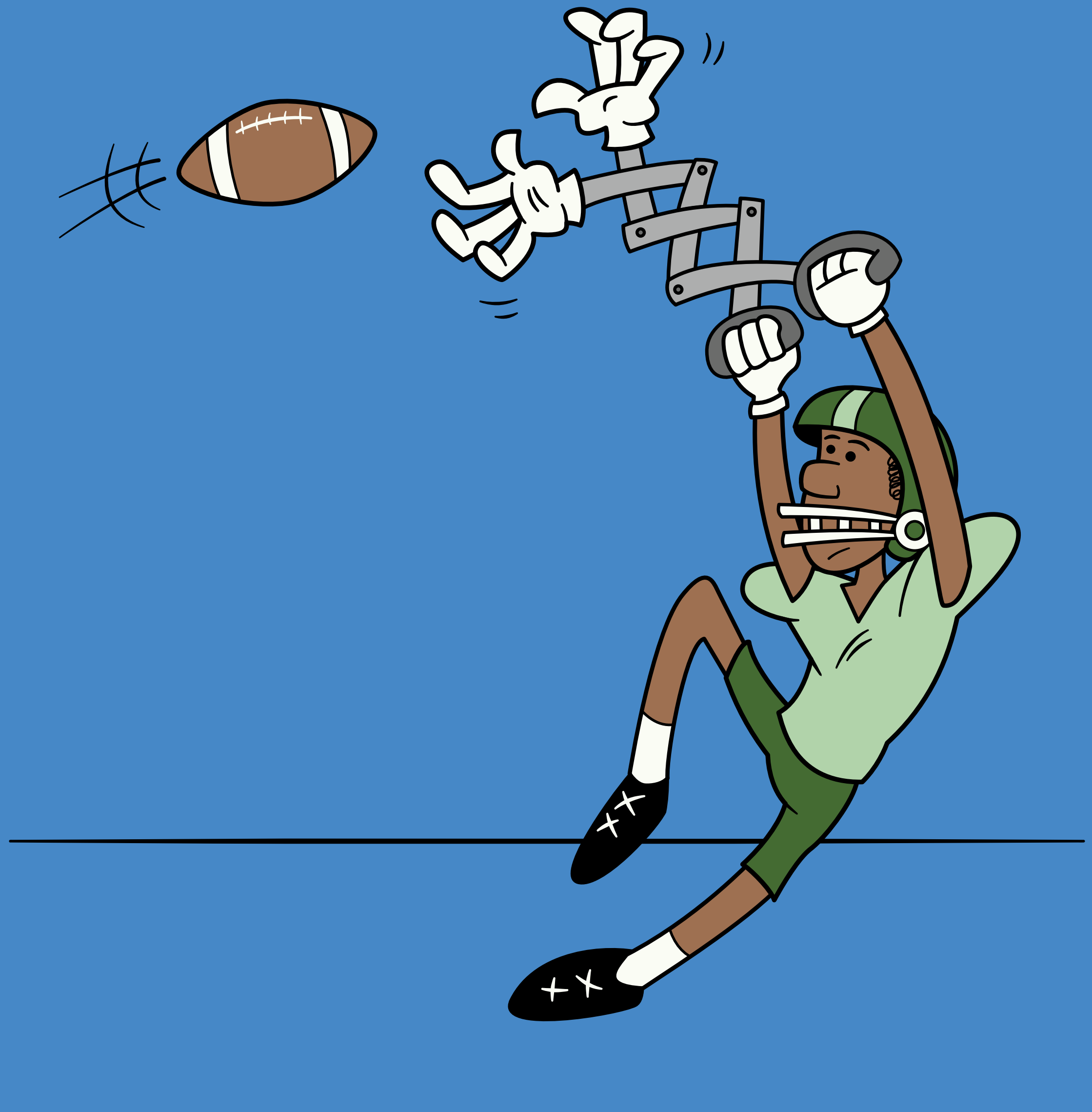
- How to associate two values with a **`Pair`**.
- How to create a simple map with **`mapOf()`** and **`mutableMapOf()`**.
- How to look up a value in a map by its key.
- How to modify a map.
- How to perform operations on a map.
- How to associate keys and values from an existing list of objects.
- How to group elements from an existing list of objects.

Well, we've learned a lot about collections over these past two chapters! Next, we're going to explore some powerful concepts that make many of those collection operations possible. Get ready for receivers and extensions!

Kotlin: An Illustrated Guide

Chapter 10

# Receivers and Extensions



## Tack new functions and properties onto any class!

Kotlin extensions can be used to add new functions and properties to existing classes—even to classes that you didn't write! In this chapter, we'll cover explicit receivers, implicit receivers, extension functions, and extension properties.

Buckle up!

# Standalone Functions and Object Functions

Way back in Chapter 2, we learned how to create functions. Here's a very simple function that puts single quotes at the beginning and the end of a **`String`**.

```
fun singleQuoted(original: String) = "'$original'"
```

*Listing 10.1 - A simple function to wrap a string in single quotes.*

As you recall, this function can be called easily.

```
val title = "The Robots from Planet X3"
val quotedTitle = singleQuoted(title)

println(quotedTitle) // 'The Robots from Planet X3'
```

*Listing 10.2 - Calling a simple function.*

And then in Chapter 4, we learned that objects can contain functions, too. For example, **`String`** objects have a function named **`uppercase()`** that returns the same string, but with all uppercase letters.

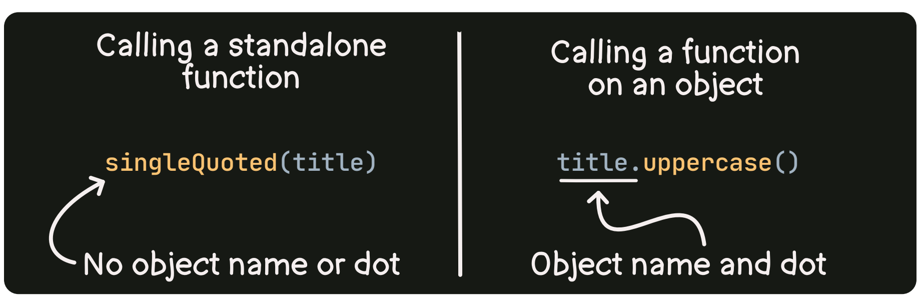
```
val title = "The Robots from Planet X3"
val loudTitle = title.uppercase()

println(loudTitle) // THE ROBOTS FROM PLANET X3
```

*Listing 10.3 - Calling a function on an object.*

When we call a function that's on an object like this, we prefix the function call with the *name of the object* and a *dot*. For this reason, this way of writing a function call is called **dot notation**.

So, there are two different *categories* of functions:

- Functions that *stand alone*, apart from an object.
- Functions that are called on an *object*.




It's easy to call a standalone function. It's also easy to call a function on an object.

However, things become more difficult when we *combine* calls to these two different types of functions in one place.

Take a look at this code, which calls one standalone function (**`singleQuoted()`**), and calls two functions with dot notation (**`removePrefix()`** and **`uppercase()`**).

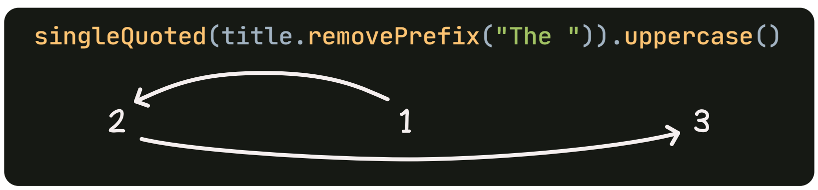
```
singleQuoted(title.removePrefix("The ")).uppercase()
```

*Listing 10.4 - Calling three functions to change a string—two functions are on an object and another is a standalone function.*

Can you figure out what order these functions will be called in?

1. First, **`removePrefix()`** is called.
2. Then, the result from that call will be used as an argument to the **`singleQuoted()`** function.
3. Finally, **`uppercase()`** will be called on the **`String`** object that is returned from **`singleQuoted()`**.

Visually, our minds have to process this expression by bouncing around—starting in the middle, then moving to the left, then moving to the right.




Imagine trying to read a book like this!


It would be easier to read and understand the code if *all three* of these function calls worked the same way, so that we could read them in a single direction.

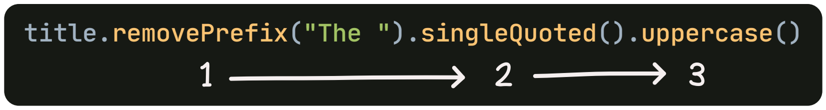
For example, if we could use *dot notation* to call the **`singleQuoted()`** function—just like we do with **`removePrefix()`** and **`uppercase()`**—then it would be very easy to follow. Here's what that would look like.

```
val newTitle = title.removePrefix("The ").singleQuoted().uppercase()
```

*Listing 10.5 - Calling three functions, each of them is a function on an object.*

Since **`singleQuoted()`** isn't a part of the **`String`** class, this code doesn't actually work yet. But it's clear to see how much easier this is to read and understand, because the functions are called in the same order that we would read them.

We can simply follow the code from *left to right*.




These calls could also be arranged vertically, one per line, like this.

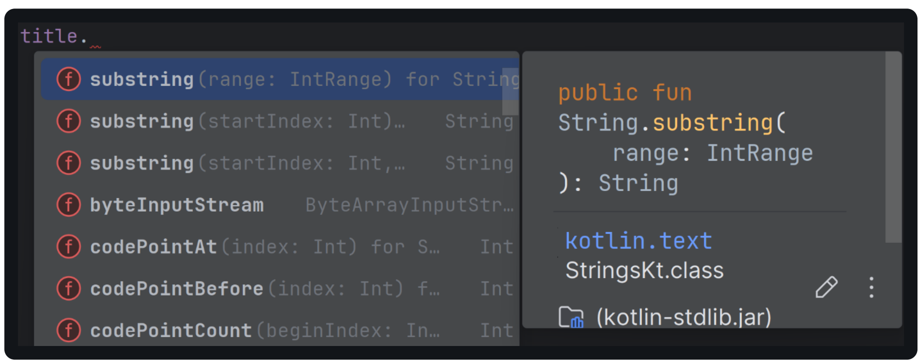
```
val newTitle = title
    .removePrefix("The ")
    .singleQuoted()
    .uppercase()
```

*Listing 10.6 - Arranging a call chain vertically.*

Again, it's natural to read—from top to bottom.[1]

Besides making the function calls consistent and easy to read, there are times when dot notation just fits well with a Kotlin developer's expectations. By convention, if a function primarily does something *to* an object or *with* an object, then we often expect that function to exist *on* the object.

Also, when using an IDE like IntelliJ IDEA, functions that are "on an object" are easier to discover.




If you've got a **`String`** object, and you wonder what functions can be called on it, just type the dot, and you'll see a list of the available functions.

This is a great way to explore classes that you're not familiar with!

So, in this chapter, our goal is to change **`singleQuoted()`** so that it can be called with a dot.

```
val newTitle = title.singleQuoted()
```

*Listing 10.7 - How we want the call site to look—calling* **`singleQuoted()`** *on an object instead of as a standalone function.*

Let's start by looking more closely at the similarities and differences between standalone functions and those that are called on an object.

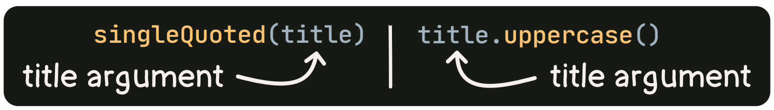
[1] When the functions are called in the same order as we would naturally read them (that is, left to right, top to bottom), developers often refer to this as a *fluent interface*. However, Martin Fowler and Eric Evans, who came up with that term, clarify that using chained function calls is only *part* of what makes an interface fluent. Read more thoughts about fluent interfaces from Martin Fowler here: https://www.martinfowler.com/bliki/FluentInterface.html

# They're Not So Different After All

These two categories of functions—standalone functions and functions that are called on an object—have more in common than you might think. Yes, the way that we have to *write* the code—that is, the **syntax**—to call the function is a little different in each case.

```
singleQuoted(title) | title.uppercase()
```

But in concept, they're actually very similar. They both start off with a `String` object, and they both return a new `String` object that is based on the original. From that standpoint, it's almost as if each of these functions takes a `String` argument. The difference is only in *where we put that argument* when we call the function.

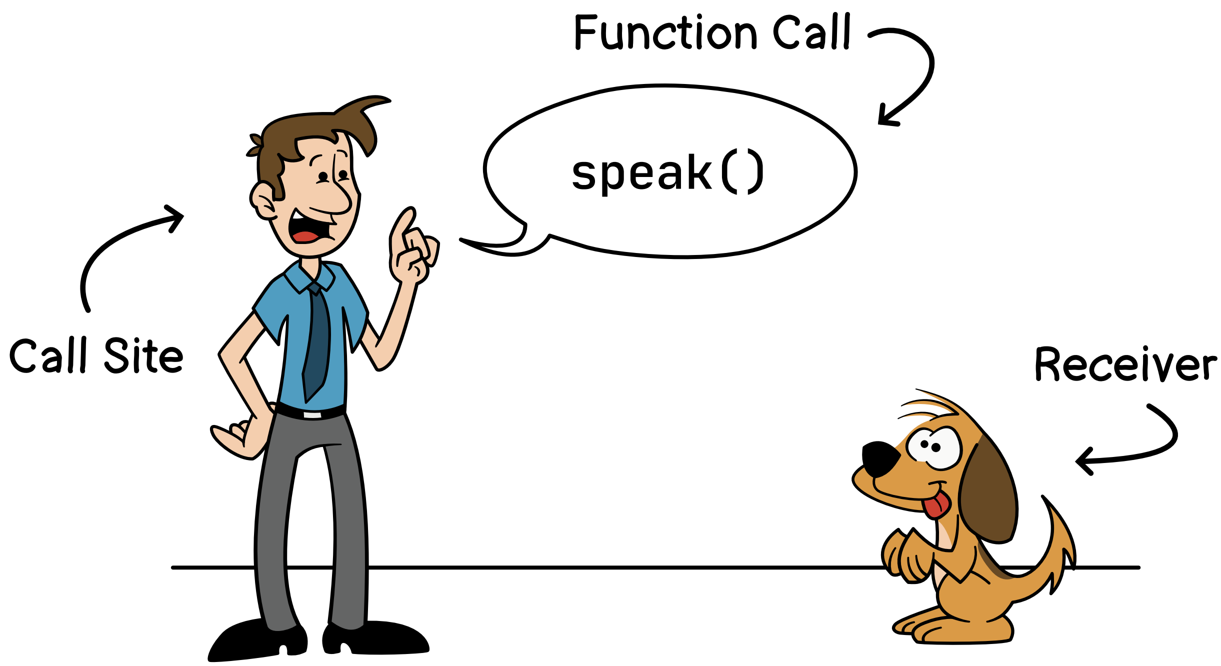



When calling a function using a dot, the *object to the left of the dot* is known as the **receiver** of the function call. Receivers are an important concept for this chapter, but they're also important for understanding upcoming concepts like scope functions and more advanced lambdas, so let's dig in!

# Introduction to Receivers

A well-trained dog knows how to bark on command. When you tell your dog Fido to "speak", you're sending him a command, and he is the receiver of that command.

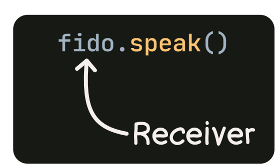
Similarly, when you call a function on an object, that object is the receiver of that function call.




Let's flesh this out further with some code. Here's a simple Dog class with some code to tell the dog to speak.

```
class Dog {
    fun speak() {
        println("BARK!")
    }
}

val fido = Dog()
fido.speak()
```

*Listing 10.8 - A simple* **`Dog`** *class, along with code that calls its* **`speak()`** *function.*




Since **`fido`** is the dog you're telling to **`speak()`**, **`fido`** is the receiver. Now, sometimes your dog doesn't need to be told to speak. Sometimes he will choose to bark on his own. Let's update the **`Dog`** class so that Fido will bark whenever he starts playing.

```
class Dog {
    fun speak() {
        println("BARK!")
    }
    fun play() {
        this.speak()
    }
}
```

*Listing 10.9 - Adding a* **`play()`** *function to the* **`Dog`** *class.*

Here, the **`play()`** function calls the **`speak()`** function. The keyword **`this`** refers to the same object that **`play()`** is called upon. In other words, when we call **`fido.play()`**, then **`speak()`** will be called on the **`fido`** object. In Listing 10.9, the *receiver* of the **`speak()`** function call is **`this`**.

We can also omit **`"this."`**—so the following code works the same as the code above.

```
class Dog {
    fun speak() {
        println("BARK!")
    }
    fun play() {
        speak()
    }
}
```

*Listing 10.10 - Omitting* **`this.`** *when calling* **`speak()`** *from inside* **`play()`**.

And now, there's no object name or dot before **`speak()`**—just the function name. Does this mean that there's no receiver here?

```
class Dog {
    fun speak() {
        println("BARK!")
    }
    fun play() {
        speak()
    }
}
```

Any receiver here?

In fact, there *is* a receiver here! Remember—any time that a function is called *on an object*, that object is the receiver. Because **`speak()`** is being called on a **`Dog`** object, that object is the receiver. Inside the **`play()`** function, we can include **`"this."`** before **`speak()`**, or we can omit it. The result is the same either way, and the receiver is the same either way.

So, **`speak()`** has a receiver here! It's just not *explicitly* stated in the code. It's *implied*.

That's why it's known as an **implicit receiver**.

```
class Dog {
    fun speak() {
        println("BARK!")
    }
    fun play() {
        speak()
    }
}

val fido = Dog()
fido.speak()
```

(Implicit Receiver)

Explicit Receiver

Contrast that with the **explicit receiver** in Listing 10.8 above. The code to the right shows two call sites for **`speak()`**—one that's using an implicit receiver, and one that's using an explicit receiver.

Wow, that's a lot of information about receivers, but we can summarize it in three points:

- A receiver is an object whose function you are calling.
- It can be *explicit*, as seen when calling a function with a dot.
- Or, it can be *implicit*, such as when one function calls another function inside the same class.

Now that we know about receivers, we can use this knowledge to get back to our original goal—updating the **`singleQuoted()`** function, so that we can call it with a dot.

## By the Way: Sometimes You Need `this`

As mentioned above, we can often omit **`this`**, but there are times when it's needed. If two functions have the same *signature*—that is, the same name, parameter types, and return type—then **`this`** can be helpful for choosing the right one.

# Introduction to Extension Functions

As it's currently written, the **`singleQuoted()`** function has a single parameter, named **`original`**, which is the string that will be wrapped with quotes. All we need to do now is to update the function so that it has a *receiver* instead of a normal function parameter.

What we have: `singleQuoted(title)`

What we want: `title.singleQuoted()`

When we want to be able to call a function with a dot, one way to do this is to *add the function to the class*. However, we can't always do that. For example, the **`String`** class is part of the Kotlin standard library, so we can't just open up its code and write a new function in it!

Thankfully, Kotlin provides a way to *extend* a class with our own functions, which can be called with a dot. These are called **extension functions**.

Let's look at the **`singleQuoted()`** function that we wrote way back at the beginning of this chapter.

```
fun singleQuoted(original: String) = "'$original'"
```

*Listing 10.11 - The original function from Listing 10.1.*

Let's change the original parameter to be the receiver, so that **`singleQuoted()`** will be an extension function.

1. First, we prefix the function name with the *type* of the receiver that we want, and add a dot. In Listing 10.11 above, we want a receiver that's a **`String`**.

2. Second, we refer to the receiver using **`this`** inside the function body.

Here's how **`singleQuoted()`** looks after making these changes.

```
fun String.singleQuoted() = "'$this'"
```

*Listing 10.12 - An extension function that does the same thing as the previous listing.*

In this code:

- **`String`** is the **receiver type**. By specifying it as **`String`**, we'll be able to call **`singleQuoted()`** on any object that is a **`String`**.

```
Receiver Type    Receiver Parameter
fun String.singleQuoted() = "'$this'"
```

- **`this`** is the **receiver parameter**. It refers to whatever object **`singleQuoted()`** is called upon, so if we call **`title.singleQuoted()`**, then **`this`** will refer to the **`title`** object.

We can easily convert a regular function to an extension function. Here's how we can do that.

1. Put the type of the parameter before the function name, and add a dot.
2. Anywhere that the parameter was used, rename it to **`this`**.
3. Finally, remove the original parameter from between the parentheses.

```
fun singleQuoted(original: String) = "'$original'"

fun String.singleQuoted() = "'$this'"
```

With these changes, whenever we call **`singleQuoted()`**, we *must* call it with a receiver, as shown here.

```
val quotedTitle = title.singleQuoted()
```

*Listing 10.13 - How to call* **`singleQuoted()`***, now that it's an extension function.*

And now, it's easy to insert a call to **`singleQuoted()`** into the middle of a call chain!

```
val title = "The Robots from Planet X3"
val newTitle = title
    .removePrefix("The ")
    .singleQuoted()
    .uppercase()

// 'ROBOTS FROM PLANET X3'
```

*Listing 10.14 - Adding a call to* **`singleQuoted()`** *in the middle of a call chain.*

Extension functions are quite common in Kotlin code. Kotlin's standard library includes many extension functions, too. In fact, you might be surprised to learn that both **`removePrefix()`** and **`uppercase()`** are not actually members of the **`String`** class—they're extension functions!

Extensions are a great way to give an existing type some new functionality, especially for classes where we can't edit the class itself. Just keep in mind that extensions cannot access **`private`** members of a class. So, even though an extension function is *called* the same way as a member function, it doesn't have access to all of the same things that a member function does!

## Nullable Receiver Types

What happens when we want to call an extension function on a nullable object? We'll get an error message.

```
val title: String? = null
val newTitle = title.singleQuoted()
```

*Listing 10.15 - **Error:** "Only safe (?.) or non-null asserted (!!.) calls are allowed on a nullable receiver of type String?"*

As you might remember from Chapter 6, we can work around it by using the safe-call operator so that `singleQuoted()` is only called when `title` is *not* null.

```
val title: String? = null
val newTitle = title?.singleQuoted()
```

*Listing 10.16 - Using a safe-call operator when the object is nullable.*

Kotlin also gives us another option, though—we can create an extension function that has a *nullable receiver type*. For example, instead of making the receiver type a non-nullable `String`, we can make it a nullable `String?`, as shown here.

```
fun String?.singleQuoted() =
    if (this == null) "(no value)" else "'$this'"
```

*Listing 10.17 - Creating an extension function for a nullable receiver type.*

Inside that function, `this` is nullable. If `singleQuoted()` is called on a null, then it returns a string that says `"(no value)"`. Otherwise, it works like the previous version of `singleQuoted()`, as in Listing 10.12.

When an extension function has a nullable receiver type, we don't *have* to call it with a safe-call operator. We can call it with a regular dot operator instead.

```
val title: String? = null
val newTitle = title.singleQuoted()

println(newTitle) // (no value)
```

*Listing 10.18 - Calling an extension function that has a nullable receiver type using a normal dot operator.*

On the other hand, we *could* still choose to call it with the safe-call operator if we want, but in that case, the function will *only* be called if the receiver is not `null`.

For example, the only difference between the following listing and the previous listing is that we changed from a regular dot operator to the safe-call operator. The result is that `newTitle` is `null` rather than `"(no value)"`.

```kotlin
val title: String? = null
val newTitle = title?.singleQuoted()

println(newTitle) // null
```

*Listing 10.19 - Calling an extension function that has a nullable receiver type using a safe-call operator.*

So, choose carefully between a dot operator and a safe-call operator, based on your expectations.

## Extension Properties

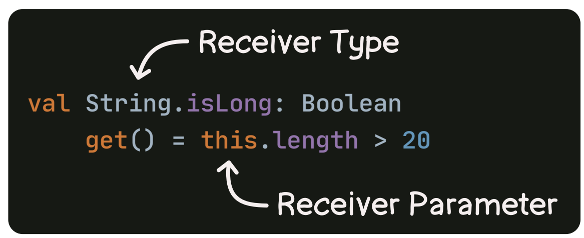
In addition to extension *functions*, we can also create extension *properties*. However, we can't use an extension property to actually store additional values inside a class. For example, it's not possible to add an ID number to a **`String`**. Still, they can be helpful for making small calculations.

Let's create an extension property that tells us if a **`String`** is longer than 20 characters.

```kotlin
val String.isLong: Boolean
    get() = this.length > 20
```

*Listing 10.20 - A simple extension property.*

Just as with an extension function, an extension property specifies the *receiver type*, and the *receiver parameter* is available as **`this`**.




As mentioned before, when calling a function or property on an *implicit receiver*, we don't need to include **`"this."`** so we could also write **`isLong`** without it.

```kotlin
val String.isLong: Boolean
    get() = length > 20
```

*Listing 10.21 - Omitting **`this.`** inside the extension property.*

We can use this property the same way as we'd use any property.

```kotlin
val string = "This string is long enough"
val isItLong = string.isLong
```

*Listing 10.22 - Using an extension property.*

Now you know how to create both extension functions and extension properties!

# Summary

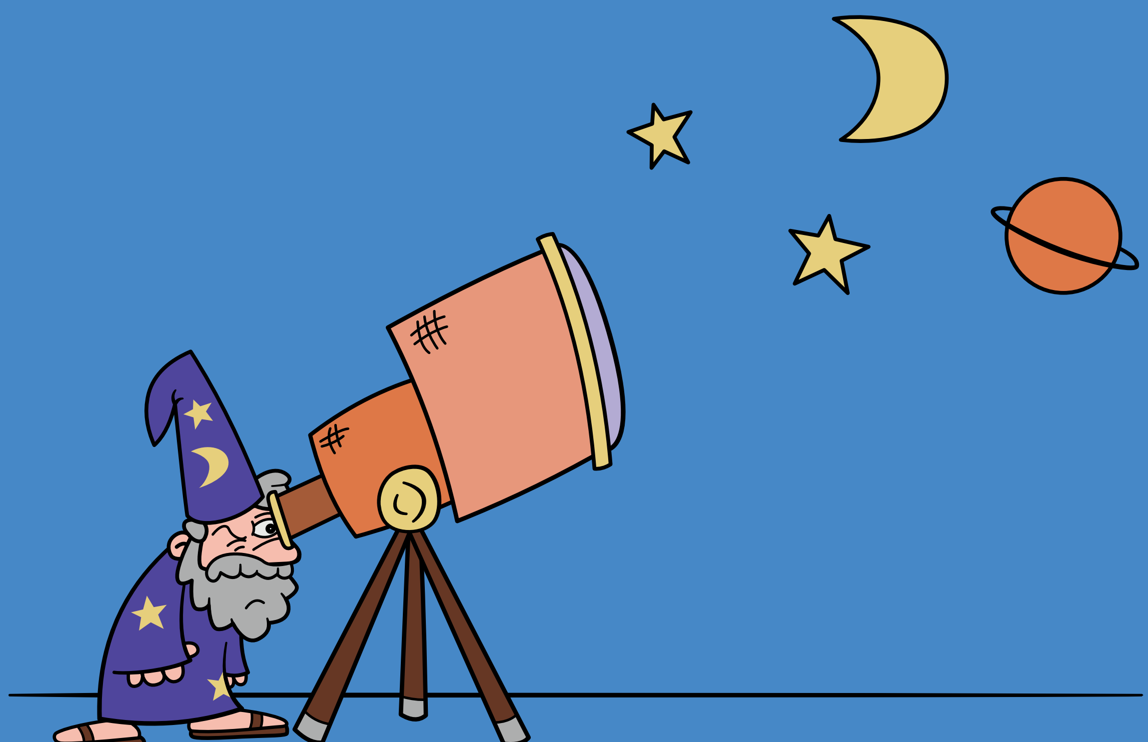
With receivers and extensions in your playbook, you can add functions and properties to types, even when you don't have access to their source code!

Here's what you tackled in this chapter:

- The difference between standalone functions and object functions.
- All about explicit and implicit receivers.
- How to create an extension function.
- How to create an extension function that has a nullable receiver type.
- How to create an extension property.

Are you ready for the next play? Huddle up for scopes and scope functions. Kotlin developers use them frequently, and in some cases, they can even be a helpful replacement for extension functions!

# Scopes and Scope Functions



## Dot notation—without your own extensions!

In the last chapter, we learned how to create extension functions, which can be called using dot notation.

In this chapter, we'll learn about scope functions, which are five particular functions that Kotlin gives us in its standard library. Before we can understand scope functions, though, it helps to first understand scopes.

# Introduction to Scopes

In Kotlin, a **scope** is a section of code where we can declare new variables, functions, classes, and more. In fact, every time that we've declared a new variable, we've declared it inside of *some* scope. For example, when we create a new Kotlin file and add a variable to it, that variable is declared within the file's scope.

```kotlin
val pi = 3.14
```

*Listing 11.1 - Declaring a variable in a top-level file scope.*

In this case, the variable **`pi`** is declared within that file's top-level scope.

```kotlin
val pi = 3.14
```

Top-Level File Scope

When we declare a class in that same file, the body of that class creates *another scope*—one that is contained *within* the top-level scope of the file. Let's create a **`Circle`** class in that file, and add a **`diameter`** property to it.

```kotlin
val pi = 3.14

class Circle(var radius: Double) {
    val diameter = radius * 2
}
```

*Listing 11.2 - Adding a `Circle` class to create another scope.*

Now we can identify *two* scopes in this file:

1. The top-level file scope, where the **`pi`** variable and the **`Circle`** class are declared.
2. The class body scope of the **`Circle`** class, where **`diameter`** is declared.

We can add new things like variables, functions, or classes to either of these scopes.

```kotlin
val pi = 3.14

class Circle(var radius: Double) {
    val diameter = radius * 2
}
```

Top-Level File Scope

Class Body Scope

## By the Way: Parameter Scopes

Technically, there's a third scope here. The parameter list of the **`Circle`** constructor (where **`radius`** is declared) also has its own scope. For simplicity, we'll mostly ignore parameter scopes in this chapter.

When one scope is contained within another, we call it a **nested scope**. In the example above, the body of the `Circle` class is a scope that is *nested* within the scope of the file.

```kotlin
val pi = 3.14

class Circle(var radius: Double) {
    val diameter = radius * 2
}
```

Nested Scope

We can take it even further. If we add a function to that class, that function's body creates yet *another* scope that's nested within the class scope, which is nested within the original scope!

```kotlin
val pi = 3.14

class Circle(var radius: Double) {
    val diameter = radius * 2

    fun circumference(): Double {
        val result = pi * diameter
        return result
    }
}
```

Top-Level File Scope

Class Body Scope

Function Body Scope

This third scope is yet *another* place where we can add new variables, functions, and classes.

A new scope is also created when we write a lambda. Let's add a new function that uses a lambda. This will add a scope for the function body and a scope for the lambda.

```kotlin
val pi = 3.14

class Circle(var radius: Double) {
    val diameter = radius * 2

    fun circumference(): Double {
        val result = pi * diameter
        return result
    }
}

fun createCircles(radii: List<Double>): List<Circle> {
    return radii.map { radius ->
        Circle(radius)
    }
}
```

Top-Level File Scope

Class Body Scope

Function Body Scope

Function Body Scope

Lambda Scope

In the code above, we can now identify *five* scopes. We can add a new variable, function, or class within any one of them![1]

Notice that, other than the outer-most scope, each scope here begins with an opening brace **{** and ends with a closing brace **}**. This isn't a hard-and-fast rule (for example, some functions have expression bodies, and therefore no braces), but can serve as a helpful way to generally identify scopes. This also means that if we indent the code consistently, it makes it easier to tell where each new scope is being introduced.

One of the most important things about scopes is that they affect *where* we can use the things that are declared inside of them. Let's look at that next!

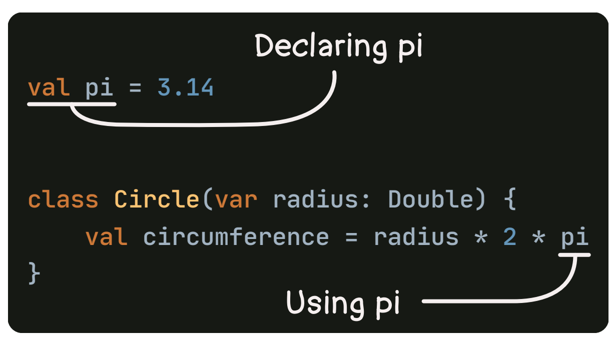
## Scopes and Visibility

As you grow up speaking a language natively, you gradually develop a sense for the rules of that language. When you were a child, your parents might have gently corrected your grammar here and there, and over time, you were eventually able to *intuit* the rules, even if you couldn't always explain them to someone.

Similarly, as you've been writing Kotlin code, you've developed a sense for *when* you can use a particular variable, function, or class.

**Visibility** is the term used to describe *where* in the code you can or cannot use something (such as a variable, function, or class). As with your native language, you can also *intuit* these visibility rules. However, you'll be a more productive Kotlin developer if you actually *know* what those rules are.

In a moment, we'll see two kinds of scopes, and how they affect visibility. As you read this next section, keep in mind the difference between *declaring* something and *using* it.




- A variable, function, or class is declared at the point where it is introduced with the **val**, **var**, **fun**, or **class** keyword.
- When you evaluate a variable, call a function, and so on, you're using it.

*Visibility* describes where in the code something can be *used*, and that is determined by where in the code that thing was *declared*. We'll see plenty of examples of this in the next sections of this chapter.

[1] There are actually more than five scopes here. As mentioned above, parameter lists have their own scopes, but you'll typically only declare parameters there. Also, depending on whether a class contains other things like secondary constructors, enum classes, and companion objects, there could be a "static" scope. In order to stay focused on the main concepts of scopes, we'll ignore those for this chapter. If you're curious, you can read all about them in the *Declarations* chapter of the Kotlin language specification.

## Statement Scopes

There are two different kinds of scopes in Kotlin, and the kind of the scope affects the visibility of the things declared inside of it. Let's start with **statement scopes**, which are easiest to understand.

The visibility rule for a statement scope is simple—we can only use something that was declared in a statement scope *after* the point where it was declared.

For example, a function body has a statement scope. Inside that function body, if we try to use a variable that hasn't yet been declared, we'll get a compiler error. In the following code, we declare a **`diameter()`** function inside the **`circumference()`** function, but try to use it *before* it was declared.

```
class Circle(val radius: Double) {
    fun circumference(): Double {
        val result = pi * diameter()
        fun diameter() = radius * 2
        return result
    }
}
```

*Listing 11.3 - **Error:** Unresolved reference: diameter.*

We can't call the **`diameter()`** function at this point in the code, because the function is declared later in the code (that is, on the next line) inside this statement scope.

To correct this error, we just need to move the line that declares **`diameter()`** so that it comes *before* the line that uses it.

```
class Circle(val radius: Double) {
    fun circumference(): Double {
        fun diameter() = radius * 2
        val result = pi * diameter()
        return result
    }
}
```

*Listing 11.4 - Declaring the **`diameter()`** function before using it in a statement scope.*

So, something that is declared inside a statement scope can only be used *after* the point that it was declared. Easy!

As we saw here, a function body is one example of a statement scopes. Other examples include constructor bodies, lambdas, and Kotlin Script files (that is, files that end in **`.kts`**).

## Declaration Scopes

A second kind of scope in Kotlin is called a **declaration scope**. Unlike statement scopes, things declared within a declaration scope can be used from a point in the code *either before or after* that declaration.

A class body is an example of a declaration scope. We can update the `Circle` class from the previous listing so that the `diameter()` function is declared in the class body (a declaration scope) instead of the `circumference()` function body (a statement scope). We'll also change `circumference` to a property to make that line similar to the `result` assignment in Listing 11.3.

```
class Circle(val radius: Double) {
    val circumference = pi * diameter()
    fun diameter() = radius * 2
}
```

*Listing 11.5 - Using the* `diameter()` *function before declaring it in a declaration scope.*

Now, even though `diameter()` is declared *after* `circumference()`, everything compiles and runs just fine.

So, in declaration scopes, things can generally be used *either before or after* the point where they are declared.

One notable exception to this rule is that variables and properties that are declared *and* used in the same declaration scope must be declared *before* they are used. So if we were to change both `circumference()` and `diameter()` to properties without changing their order, we would get an error from the compiler.

```
class Circle(val radius: Double) {
    val circumference = pi * diameter
    val diameter = radius * 2
}
```

*Listing 11.6 - **Error:** Variable diameter must be initialized.*

As we saw, a class body is one example of a declaration scope. The top level of a regular Kotlin file (when it ends in `.kt`) is another example.

## Nested Scopes and Visibility

In general, if you want to know what variables, functions, and classes are available to you inside a particular scope, you can "crawl your way out" from that scope, toward the outermost scope—the one at the file level. As you're crawling:

1. If you crawl into a statement scope, you can only use things declared earlier in the scope.

2. If you crawl into a declaration scope, you can use things declared either earlier or later in the scope.

Let's demonstrate how this works. We'll start with a file that has the following code.

```
val pi = 3.14

fun main() {
    val radii = listOf(1.0, 2.0, 3.0)

    class Circle(
        val radius: Double
    ) {
        fun circumference(): Double {
            val multiplier = 2.0
            // Which variables are visible here?
            val diameter = radius * multiplier
            return multiplier * pi * radius
        }

        val area = pi * radius * radius
    }

    val areas = radii.map {
        Circle(it).area
    }
}
```

*Listing 11.7 - Code that will be used to demonstrate scope crawling.*

Which variables and properties are visible at the comment?

To answer that question, we can start by identifying which of the scopes in this listing are *statement scopes* and which are *declaration scopes*.

Remember:

- Function bodies and lambdas have a statement scope.
- Class bodies and the file itself have declaration scopes.

The following five annotated code listings show the different declaration and statement scopes in Listing 11.7. We're starting at the comment (in the listings below, it has a yellow dot to help you find it), which we'll call the *starting point*, and our goal is to figure out which variables are visible at that point in the code.

Note that these five numbered items correspond to the five illustrated code listings that follow.

1. The starting point is inside a *statement scope*.
2. Because things declared in a statement scope can only be used *after* they have been declared, we start by scanning only upward—not downward. When we scan upward, we run into the `multiplier` variable. So,

the **`multiplier`** variable is visible at the starting point. The **`diameter`** variable, however, is not visible, because it's declared after the starting point.

3. Having scanned this statement scope, we're now ready to crawl into the next scope outward—that is, we crawl into the scope that contains the **`circumference()`** function. This is a class body, which has a declaration scope. With a declaration scope, we scan both upward and downward.

   Scanning in both directions, we come across both the **`radius`** parameter, which is declared before the function, and **`area`**, which is declared after the function. So, both of these variables are also visible at the starting point.

4. Next, we crawl out to the containing scope—that is, the scope of the **`main()`** function. Because this is a function body (and therefore has a statement scope), we crawl only upward. Scanning upward, we run into the **`radii`** variable, which is also visible at the starting point. However, the **`areas`** variable is not visible, because it's below.

5. Finally, we crawl out to the top-level file scope. Files have a declaration scope, so we scan both directions.

   The **`pi`** variable is found when scanning upward, and there are no variables found when scanning downward in this scope.

```kotlin
val pi = 3.14

fun main() {
    val radii = listOf(1.0, 2.0, 3.0)

    class Circle(
        val radius: Double
    ) {
        fun circumference(): Double {
            val multiplier = 2.0
            // Which variables are visible here?
            val diameter = radius * multiplier
            return multiplier * pi * radius
        }

        val area = pi * radius * radius
    }

    val areas = radii.map {
        Circle(it).area
    }
}
```

Declaration Scope

Statement Scope

Declaration Scope

Statement Scope

Statement Scope

1

```kotlin
val pi = 3.14

fun main() {
    val radii = listOf(1.0, 2.0, 3.0)

    class Circle(
        val radius: Double
    ) {
        fun circumference(): Double {
            val multiplier = 2.0
            // Which variables are visible here?
            val diameter = radius * multiplier
            return multiplier * pi * radius
        }

        val area = pi * radius * radius
    }

    val areas = radii.map {
        Circle(it).area
    }
}
```

Declaration Scope

Statement Scope

Declaration Scope

Statement Scope

Statement Scope

2

```kotlin
val pi = 3.14

fun main() {
    val radii = listOf(1.0, 2.0, 3.0)

    class Circle(
        val radius: Double
    ) {
        fun circumference(): Double {
            val multiplier = 2.0
            // Which variables are visible here?
            val diameter = radius * multiplier
            return multiplier * pi * radius
        }

        val area = pi * radius * radius
    }

    val areas = radii.map {
        Circle(it).area
    }
}
```

Declaration Scope

Statement Scope

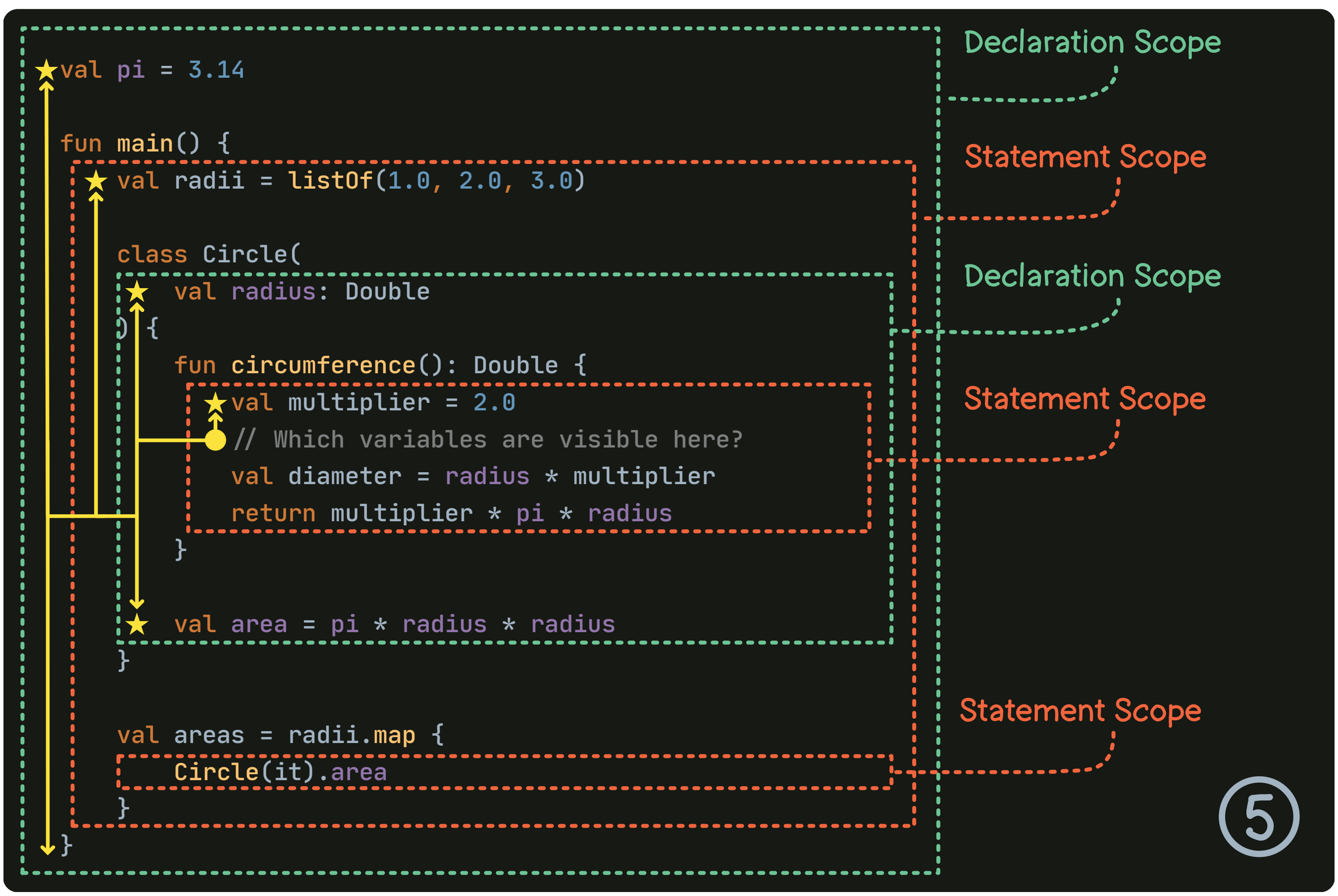
Declaration Scope

Statement Scope

Statement Scope

3


Declaration Scope
val pi = 3.14
fun main() {
Statement Scope
val radii = listOf(1.0, 2.0, 3.0)
class Circle(
Declaration Scope
val radius: Double
) {
fun circumference(): Double {
Statement Scope
val multiplier = 2.0
// Which variables are visible here?
val diameter = radius * multiplier
return multiplier * pi * radius
}
val area = pi * radius * radius
}
Statement Scope
val areas = radii.map {
Circle(it).area
}
}
4


Declaration Scope
val pi = 3.14
fun main() {
Statement Scope
val radii = listOf(1.0, 2.0, 3.0)
class Circle(
Declaration Scope
val radius: Double
) {
fun circumference(): Double {
Statement Scope
val multiplier = 2.0
// Which variables are visible here?
val diameter = radius * multiplier
return multiplier * pi * radius
}
val area = pi * radius * radius
}
Statement Scope
val areas = radii.map {
Circle(it).area
}
}
5

So, these are the variables and properties that are visible at the comment.

- `pi`
- `radii`
- `radius`
- `multiplier`
- `area`

Although we concerned ourselves only with variables and properties here, note that the same scanning approach works for other things as well, such as functions and classes. So, at the starting point, it's also possible to:

- Call the `main()` function.
- Instantiate a new `Circle` object.
- Call the `circumference()` function (from inside itself).

## By the Way: Parameter Scopes, Again!

For simplicity, I'm treating the parameter lists (such as the one containing the `radius` constructor parameter here) as part of the function or class body that they pertain to. Technically, a parameter list has its own scope, which is actually *adjacent* to its corresponding function or class body scope. However, these parameter scopes are *linked* to their body scope, which makes the parameters visible inside that body.

Again, you've probably developed an intuition around most of these rules. And as you write Kotlin from day to day, you'll normally just rely on the compiler and IDE to tell you whether something is visible at a particular point in code. Still, it's helpful to know the rules, so that you can structure your code the right way, ensuring that each thing has the visibility you intend for it to have!

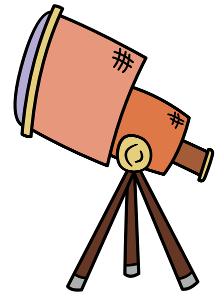
## Best Practice: Limiting Visibility

It's usually a good idea to give things the *least* amount of visibility necessary. This is especially true for variables that are declared with the `var` keyword. When these kinds of variables are declared at the top-level scope, they can be evaluated and assigned from *anywhere* in the code. This can make it difficult to know when and why the value is changing as the code runs.

By limiting its visibility, there are fewer places in the code that are able to use or change the value. Troubleshooting becomes much easier when there's less code to sift through!

Now that we've got a solid understanding of scopes and visibility, we're ready to dive into *scope functions!*

# Introduction to Scope Functions



There are five functions in Kotlin's standard library that are designated as *scope functions*. Each of them is a higher-order function that is typically called with a lambda, which introduces a new statement scope. The point of a scope function is to take an existing object—called a **context object**[1]—and represent it in a particular way inside that new scope.

Let's start with a simple example—a scope function named `with()`.

## `with()`

When we need to use the same variable over and over again, we can end up with a lot of duplication. For example, suppose we need to update an address object.

```
address.street1 = "9801 Maple Ave"
address.street2 = "Apartment 255"
address.city = "Rocksteady"
address.state = "IN"
address.postalCode = "12345"
```

*Listing 11.8 - Updating many properties of an* `address` *object.*

When *writing* this code, it's tedious to type `address` on each line, and when *reading* this code, seeing `address` on each line doesn't really make it any easier to understand. This duplication is just "noise" that actually *detracts* from the important thing on each line—the property that is being updated.

We can use the `with()` scope function to introduce a new scope that makes the `address` object an implicit receiver.

Here's how it looks.

```
with(address) {
    street1 = "9801 Maple Ave"
    street2 = "Apartment 255"
    city = "Rocksteady"
    state = "IN"
    postalCode = "12345"
}
```

*Listing 11.9 - Using* `with()` *so that each property assignment does not need to be prefixed with* `address`.

[1] The term *context object* is used in the official Kotlin documentation for scope functions, so it's used here as well. If you're an Android developer, this could be confusing, since Android has a specific `Context` class. Keep in mind that these are two entirely different concepts. You can use a scope function with any object.

The **`with()`** function is called with two arguments:

1. The object that you want to become an implicit receiver. This is the *context object*. Here, it's **`address`**.
2. A lambda in which the context object will be the implicit receiver.

Context object

```
with(address) {
    street1 = "9801 Maple Ave"
    street2 = "Apartment 255"
    city = "Rocksteady"
    state = "IN"
    postalCode = "12345"
}
```

Lambda

As you probably recall from the [last chapter](), an implicit receiver can be used with no variable name at all, so inside the lambda above, we can assign values to **`street1`**, **`street2`**, and so on, without prefixing the name of the variable as we had to do in Listing 11.8.

So again, the **`with()`** scope function introduces a new scope (the lambda) in which the context object is represented as an implicit receiver.

The remaining four scope functions are all [extension functions](). Next, let's look at one called **`run()`**, because it's very similar to **`with()`**.

# run()

The **`run()`** function works the same as **`with()`**, but it's an extension function instead of a normal, top-level function.[1] This means we'll need to invoke it with [dot notation](). Let's rewrite Listing 11.9 so that it uses **`run()`** instead of **`with()`**.

```
address.run {
    street1 = "9801 Maple Ave"
    street2 = "Apartment 255"
    city = "Rocksteady"
    state = "IN"
    postalCode = "12345"
}
```

*Listing 11.10 - Using* **`run()`** *so that each property assignment does not need to be prefixed with* **`address`**.

Other than the first line, you'll notice that this code listing is identical to the previous one. The context object is passed as a receiver instead of a regular function argument, but the code inside the lambda is the same.

[1] There's also a top-level function named **`run()`**, which can be helpful when you need to squeeze multiple statements into a spot where Kotlin expects a single expression. We're not going to cover that version of the function in this book, though.

Context object

```
address.run {
    street1 = "9801 Maple Ave"
    street2 = "Apartment 255"
    city = "Rocksteady"
    state = "IN"
    postalCode = "12345"
}
```

Lambda

Even though **`run()`** and **`with()`** are very similar, **`run()`** does have some different characteristics because it's an extension function. For instance, we saw in the last chapter how extension functions can be inserted into a call chain. In fact, instead of defining our own extension functions for use in a call chain, we can often use a scope function like **`run()`**.

For example, in the last chapter, we created a very simple extension function called **`singleQuoted()`** (in Listing 10.12), and called it in the middle of a call chain (in Listing 10.14).

```
val title = "The Robots from Planet X3"
val newTitle = title
    .removePrefix("The ")
    .singleQuoted()
    .uppercase()

// 'ROBOTS FROM PLANET X3'
```

*Listing 11.11 - Code assembled from listings in Chapter 10.*

Because **`singleQuoted()`** is just a single expression, we can easily remove the **`singleQuoted()`** function entirely, and replace it with a simple call to **`run()`**, like this.

```
val title = "The Robots from Planet X3"
val newTitle = title
    .removePrefix("The ")
    .run { "'$this'" }
    .uppercase()

// 'ROBOTS FROM PLANET X3'
```

*Listing 11.12 - Replacing the* **`singleQuoted()`** *extension function with a call to the* **`run()`** *function.*

The **`run()`** function returns the result of its lambda, so the code in this listing works identically to Listing 11.11 above. Of course, if you need to make a string single quoted in lots of places in your code, you'd be better off sticking with the **`singleQuoted()`** extension function. That way, if you need to change the way it works, you can fix it in one spot instead of lots of places. If you've only got a single call site, though, a scope function can be a good option!

Another advantage of using **`run()`** instead of **`with()`** is that we can use the safe-call operator to handle cases where the context object might be **`null`**. We'll look at this more closely toward the end of this chapter.

For now, these are the important things to remember about **`run()`**:

1. Inside the lambda, the context object is represented as the implicit receiver.
2. The **`run()`** function returns the result of the lambda.


Next, let's take a look at another scope function, called **`let()`**.

# `let()`

**`let()`** might be the most frequently-used scope function. It's very similar to **`run()`**, but instead of representing the context object as an *implicit receiver*, it's represented as the *parameter* of its lambda. Let's rewrite the previous listing to use **`let()`** instead of **`run()`**.

```
val title = "The Robots from Planet X3"
val newTitle = title
    .removePrefix("The ")
    .let { titleWithoutPrefix -> "'$titleWithoutPrefix'" }
    .uppercase()

// 'ROBOTS FROM PLANET X3'
```

*Listing 11.13 - Single-quoting a title with the `let()` function.*

This is very similar to the previous listing, but instead of using **`this`**, we used a lambda parameter called **`titleWithoutPrefix`**. This parameter name is pretty long. Let's change it to use the implicit **`it`**, so that it will be nice and concise.

```
val title = "The Robots from Planet X3"
val newTitle = title
    .removePrefix("The ")
    .let { "'$it'" }
    .uppercase()

// 'ROBOTS FROM PLANET X3'
```

*Listing 11.14 - Single-quoting a title with the `let()` function, using the implicit `it` lambda parameter.*

As with **`run()`** and **`with()`**, the **`let()`** function returns the result of the lambda.

| | Context object is implicit receiver | Context object is lambda parameter |
|---|---|---|
| Returns result of lambda | `obj.run { }` | `obj.let { }` |

## By the Way: `let()` vs. `map()`

In some ways, the **`let()`** function is similar to the **`map()`** function that we learned about in Chapter 8 when we looked at collection operations. However, whereas the **`map()`** function maps each *element* in the receiver, the **`let()`** function maps the receiver itself.

A scope function that's similar to **`let()`** is called **`also()`**. Let's look at that next.

# `also()`

As with **`let()`**, the **`also()`** function represents the context object as the lambda parameter, too. However, unlike **`let()`**, which returns the *result of the lambda*, the **`also()`** function returns the *context object*. This makes it a great choice for inserting into a call chain when we want to do something "on the side"—that is, without changing the value at that point in the chain.

For example, we might want to print out the value at some point in the call chain. Here's the code from Listing 11.11, with **`also()`** inserted after the call that removes the prefix.

```
val title = "The Robots from Planet X3"
val newTitle = title
    .removePrefix("The ")
    .also { println(it) } // Robots from Planet X3
    .singleQuoted()
    .uppercase()

// 'ROBOTS FROM PLANET X3'
```

*Listing 11.15 - Using* **`also()`** *in a call chain to print out a value.*

The **`also()`** call here prints out the result of **`title.removePrefix("The ")`**, without interfering with the rest of the call chain. Regardless of whether we include or omit the line with the **`also()`** call, the **`singleQuoted()`** call will be called upon the same value—**`"Robots from Planet X3"`**.

By the way, as you might remember from Chapter 7, we can use a function reference instead of a lambda, so we could choose to write the previous code listing like this.

```
val title = "The Robots from Planet X3"
val newTitle = title
    .removePrefix("The ")
    .also(::println) // Robots from Planet X3
    .singleQuoted()
    .uppercase()

// 'ROBOTS FROM PLANET X3'
```

*Listing 11.16 - Using `also()` with a function reference.*

Here's how `also()` fits in among `run()` and `let()`.

| | Context object is implicit receiver | Context object is lambda parameter |
|---|---|---|
| Returns result of lambda | `obj.run { }` | `obj.let { }` |
| Returns context object | | `obj.also { }` |

As you can see, we've roughly created a chart, and there's one spot that's empty. Let's fill in that last spot as we look at the final scope function, `apply()`.

# `apply()`

Like `also()`, the `apply()` function returns the *context object* rather than the result of the lambda. However, like `run()`, the `apply()` function represents the context object as the *implicit receiver*. We can update Listing 11.15 to use `apply()` instead of `also()`, and it would do the same thing.

```
val title = "The Robots from Planet X3"
val newTitle = title
    .removePrefix("The ")
    .apply { println(this) } // Robots from Planet X3
    .singleQuoted()
    .uppercase()

// 'ROBOTS FROM PLANET X3'
```

*Listing 11.17 - Using `apply()` to print out the value in a call chain. This works, but most Kotlin developers favor `also()` for this situation.*

However, in practice, Kotlin developers would typically prefer to use `also()` in this case. The `apply()` function really shines when you want to customize an object after you construct it. For example, after we call a constructor, we might want to set some other property on that object, or call one of its functions to initialize it—that is, to make the object ready for use.

```
val dropTarget = DropTarget().apply {
    addDropTargetListener(myListener)
}
```

*Listing 11.18 - Using* `apply()` *to initialize a* `DropTarget` *immediately after constructing it. It's constructed and initialized in a single expression.*

With this, we can fill out the remaining spot on the chart.

| | Context object is implicit receiver | Context object is lambda parameter |
|---|---|---|
| Returns result of lambda | `obj.run { }` | `obj.let { }` |
| Returns context object | `obj.apply { }` | `obj.also { }` |

As this chart shows, the scope functions are all similar, but they differ on two aspects:

1. How they refer to the context object.
2. What they return.

The `with()` function has been omitted from this chart, because it's the same thing as `run()`, except that it's a traditional function instead of an extension function.

With all these scope functions to choose from, how can we know which one to use in each situation?

# Choosing the Most Appropriate Scope Function

When deciding which scope function to use, start by asking yourself, "what do I need the scope function to return?"

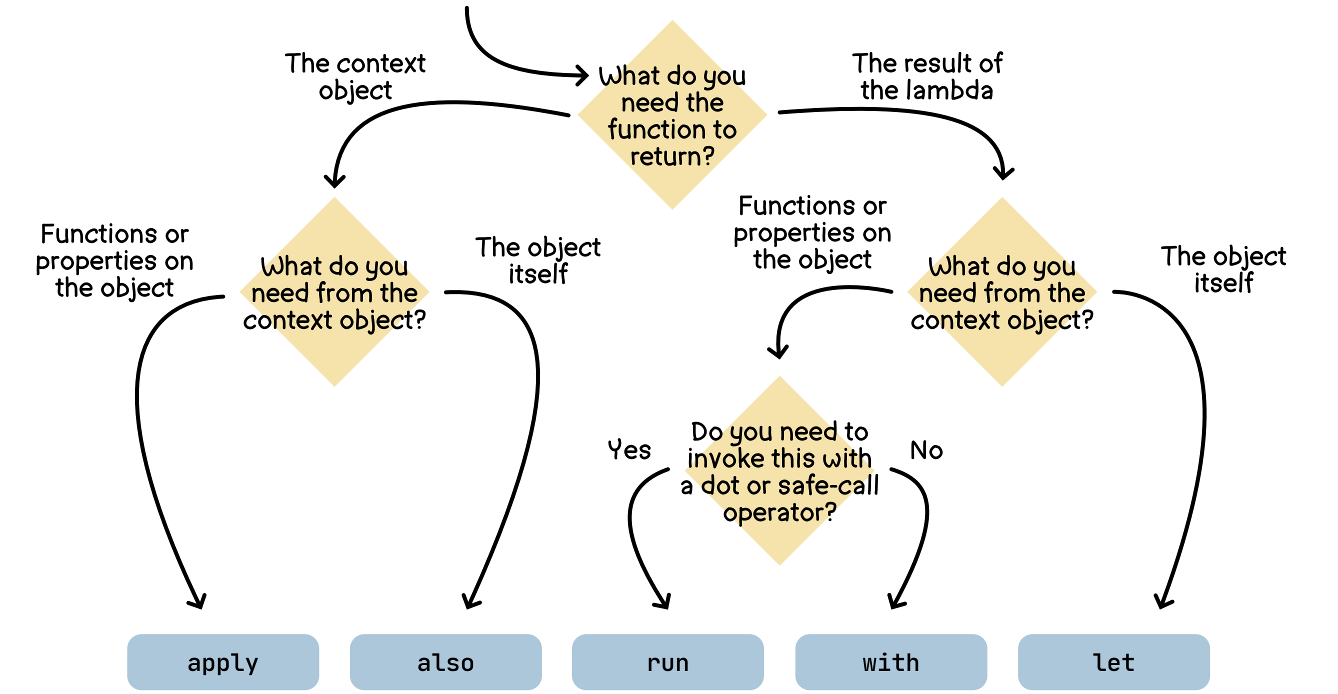
- If you need the *lambda result*, narrow your options down to either `let()` or `run()`.
- If you need the *context object*, narrow your options down to either `also()` or `apply()`.

After that, choose between the remaining two options based on your preference for how to represent the context object inside the lambda.

- If you need to use functions or properties on the object but not the object itself, then `run()` or `apply()` would probably be a good fit.
- Otherwise, `let()` or `also()` generally would be a good way to go.

Use the flowchart on the next page to help you decide which scope function to use in different situations.

## Which Kotlin scope function should I use?




There's one other caveat to consider—it's possible to create a variable or lambda parameter with the same name as a variable from an outer scope, and it's usually best to avoid that. Let's look at that next.

## Shadowing Names

When a nested scope declares a name for a variable, function, or class that's also declared in an outer scope, we say that the name in the outer scope is **shadowed** by the name in the inner scope. Here's a simple example where both a book and a chapter have a `title`.

Inside the function body here this property is shadowed by this parameter because they have the same name.

```
class Book(val title: String) {
    fun printChapter(number: Int, title: String) {
        println("Chapter $number: $title")
    }
}
```

It's perfectly valid to shadow names like this, but there are a few things to keep in mind.

First, when reading code like this, it's easy to get confused, thinking that you're referring to the name from the *outer* scope.

Second, it is more difficult—and sometimes impossible—to refer to a variable that's declared in an outer scope from an inner scope that has shadowed that variable's name.

Sometimes there are solutions—in the example above, we could still refer to the book's title with **`this.title`**. In cases when the shadowed variable is at the top level, we can refer to it by prefixing it with the package name. But in some cases, our only option might be to rename one of the two names.

So in general, it's best to avoid shadowing.

## Shadowing and Implicit Receivers

An interesting form of shadowing occurs when an *implicit receiver* is shadowed by the *implicit receiver* of a nested scope. And it works differently depending on whether we include or omit the **`this`** prefix!

For example, let's say we've got classes and objects for a **`Person`** and a **`Dog`**.

```
class Person(val name: String) {
    fun sayHello() = println("Hello!")
}

class Dog(val name: String) {
    fun bark() = println("Ruff!")
}

val person = Person("Julia")
val dog = Dog("Sparky")
```

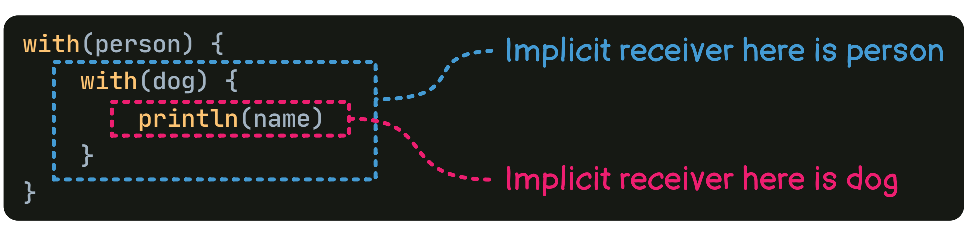
*Listing 11.19 - Two classes, and two objects, which will be used to demonstrate shadowing of implicit receivers.*

Now, we can shadow the implicit receiver if we nest one **`with()`** call inside another **`with()`** call, like this.

```
with(person) {
    with(dog) {
        println(name)
    }
}
```

*Listing 11.20 - Shadowing the **`person`** implicit receiver with the **`dog`** implicit receiver.*

In the outer scope, the implicit receiver is **`person`**, but in the inner scope, the implicit receiver is **`dog`**.



As you'd probably guess, **`name`** inside that innermost scope refers to the **`name`** of the **`dog`** object, so it's **`Sparky`**. We can also call **`bark()`** on that object.

```
with(person) {
    with(dog) {
        println(name) // Prints Sparky from the dog object
        bark()        // Calls bark() on the dog object
    }
}
```

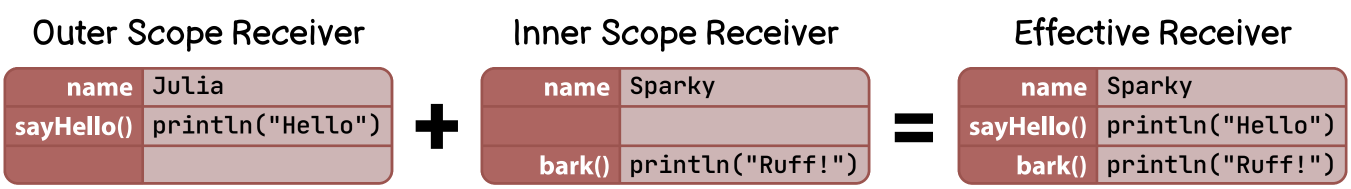
*Listing 11.21 - Invoking a property and a function on the* **`dog`** *implicit receiver.*

But here's the fun part—in that same scope, we can also call **`sayHello()`** on the **`person`** object without explicitly prefixing it with **`person`**!

```
with(person) {
    with(dog) {
        println(name) // Prints Sparky from `dog`
        bark()        // Calls bark() on `dog`
        sayHello()    // Calls sayHello() on `person`
    }
}
```

*Listing 11.22 - Invoking a function on the* **`person`** *implicit receiver from a scope where* **`dog`** *is the primary implicit receiver.*

So, in this example, both **`person`** and **`dog`** contribute to the implicit receiver in that innermost scope. We can visualize it like this.




In other words, the *effective* implicit receiver becomes a combination of *all* implicit receivers from the innermost scope to the outermost scope. When a name conflict exists (for example, both **`Person`** and **`Dog`** have a **`name`** property), priority is given to the inner scope.

## Shadowing, Implicit Receivers, and `this`

Now, all of that is true when we use the implicit receiver *without* the **`this`** keyword. However, when we refer to the implicit receiver *with* the prefix **`this`**, it will *only* have the functions and properties from the implicit receiver of the innermost scope.

In the example above, this means that **`this`** will refer to the **`dog`** *without* any contributions from the **`person`** object.

To demonstrate this, let's try adding **`"this."`** before **`name`**, **`bark()`**, and **`sayHello()`**.

```
with(person) {
    with(dog) {
        println(this.name) // Prints Sparky from `dog`
        this.bark()        // Calls bark() on `dog`
        this.sayHello()    // Compiler error here!
    }
}
```

*Listing 11.23 - **Error:** Unresolved reference: sayHello.*

This works fine for **`this.name`** and **`this.bark()`**. However, **`this.sayHello()`** gives us an error, because **`this`** *only* refers to the **`dog`**.

So, just remember:

1. When using **`this`**, it will *only* refer to the exact implicit receiver in that scope.
2. When omitting **`this`**, the effective receiver is a combination of the implicit receivers, from the innermost to the outermost scope.

Before we wrap up this chapter, let's look at how scope functions are used with null-safety features in Kotlin.

# Scope Functions and Null Checks

Other than **`with()`**, all of the scope functions are extension functions. As with all extension functions, we can use the safe-call operator when calling them, so that they're only *actually* called if the receiver is not **`null`**, as we saw in the previous chapter.

The safe-call operator is often used with scope functions. In fact, many Kotlin developers use **`let()`** with the safe-call operator to run a small block of code whenever the object is not **`null`**. For example, when we first learned about nulls in Chapter 6, we needed to make sure the code would only order coffee when the customer had a payment.

Here's a code snippet inspired by Listing 6.19 from that chapter.

```
if (payment != null) {
    orderCoffee(payment)
}
```

*Listing 11.24 - Using a conditional to call **`orderCoffee()`** only when payment is present, roughly copied from Chapter 6.*

There's absolutely nothing wrong with writing the code this way. However, it's also common for Kotlin developers to write this code with a scope function and safe-call operator.

```
payment?.let { orderCoffee(it) }
```

*Listing 11.25 - Using a scope function to call* `orderCoffee()` *only when payment is present.*

It's good to be able to recognize both ways of expressing this. The second way is especially helpful when we need to insert it into a call chain, of course.

In some cases, we might also have an `else` with a conditional, like this.

```
if (payment != null) {
    orderCoffee(payment)
} else {
    println("I can't order coffee today")
}
```

*Listing 11.26 - A simple* `if-else` *conditional that checks for nulls.*

To get the same effect with a scope function, we can use an elvis operator to express the `else` case.

```
payment?.let { orderCoffee(it) }
    ?: println("I can't order coffee today")
```

*Listing 11.27 - Rewriting the* `if-else` *null-check conditional so that it uses a scope function.*

Good ol' fashioned `if`/`else` conditionals are easy to understand for most developers, though, so consider starting there, only using the scope function / safe-call / elvis approach for null checks when it fits better with the surrounding context, such as inside a call chain.

# Summary

Now that you've got an understanding of scopes and scope functions, you'll be able to put them to use in your own projects. Code written with scope functions can be easier to read, but don't overdo it! If you use scope functions everywhere, or if you start using one scope function inside the lambda of another, it can actually make the code more difficult to understand. When used wisely, though, scope functions can improve clarity.

You scoped out a lot in this chapter, including:

- What a scope is, and how it affects the visibility of code elements like variables, functions, and classes.
- The difference between statement scopes and declaration scopes.
- The five scope functions—`with()`, `run()`, `let()`, `also()`, and `apply()`.
- Guidance about how to choose the most appropriate scope function.

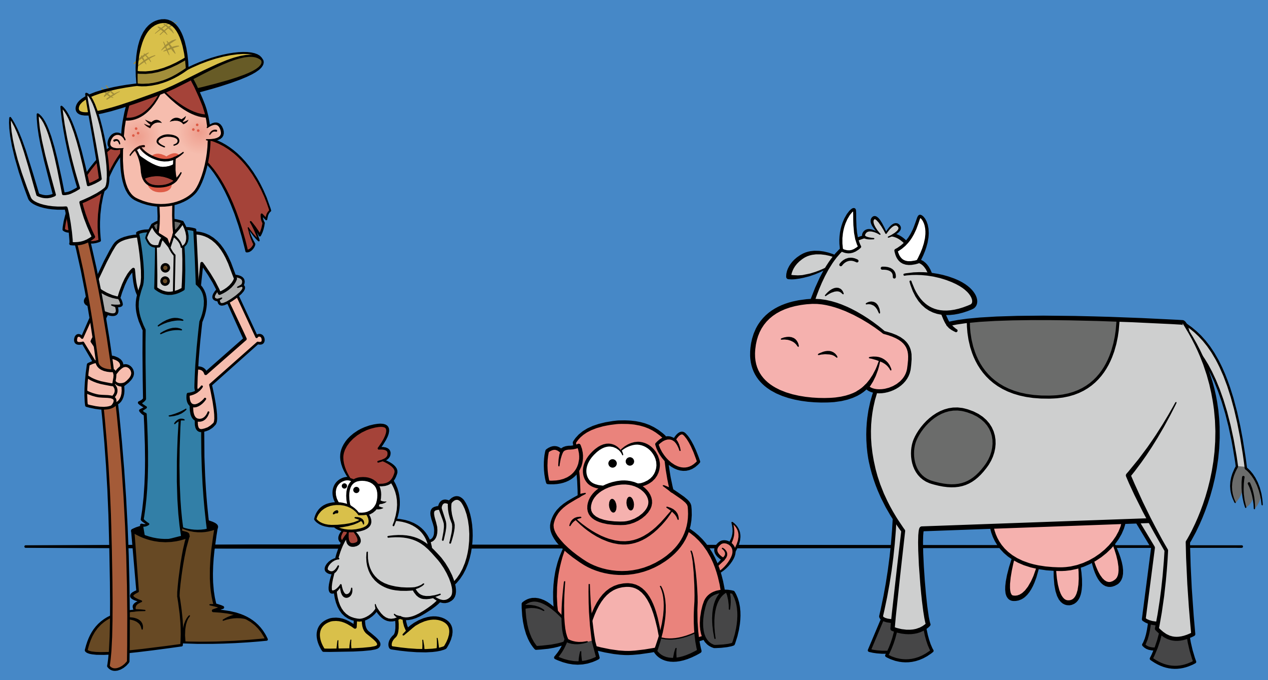
- How shadowing affects names and receivers.
- How to use scope functions for null checks.

In the next chapter, we'll focus on interfaces, subtypes, and supertypes, exploring how different types relate to each other in Kotlin's type system.

Kotlin: An Illustrated Guide

Chapter 12

# Introduction to Interfaces



## Types… supertypes… subtypes!

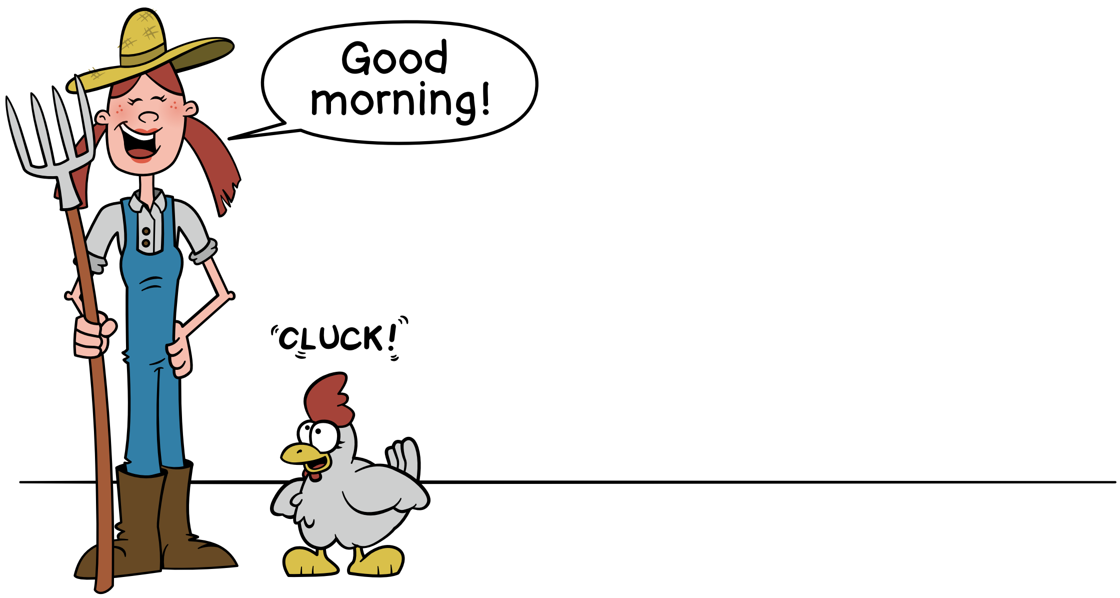
Ever since Chapter 1, we've used a variety of built-in Kotlin types, like `Int`, `String`, and `Boolean`. Then in Chapter 4, we introduced our own custom types, like `Circle`, by writing classes.

In this chapter, we'll dive into *interfaces*, which allow you to declare that a single object has more than one type at a time! Interfaces are a powerful language feature, and when used well, they can take your code to the next level.

We've got lots of fun stuff to cover, so let's get started!

# Sue Starts a Farm

Sue just bought a lot of land out in the country, and she's ready to start her farm! To kick things off, she got her very first chicken, named Henrietta. Every morning, Sue greets Henrietta, and Henrietta faithfully clucks a greeting back to Sue.




Let's write some Kotlin code to represent Henrietta the chicken and Farmer Sue.

```
class Chicken(val name: String, var numberOfEggs: Int = 0) {
    fun speak() = println("Cluck!")
}

class Farmer(val name: String) {
    fun greet(chicken: Chicken) {
        println("Good morning, ${chicken.name}!")
        chicken.speak()
    }
}
```

*Listing 12.1 - Classes to represent a chicken and a farmer.*

Now, we can instantiate the two classes, and Sue can greet Henrietta.

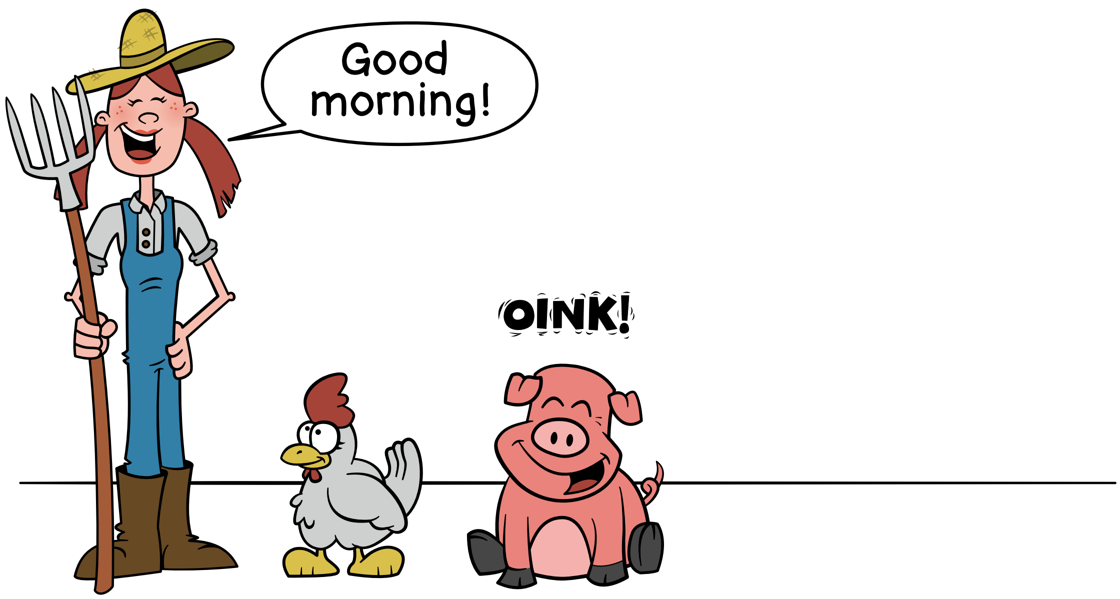
```
val sue = Farmer("Sue")
val henrietta = Chicken("Henrietta")

sue.greet(henrietta)
```

*Listing 12.2 - Instantiating classes, and calling the* `greet()` *function.*

When we run this, we get the following output.

```
Good morning, Henrietta!
Cluck!
```

Now that Sue's farm is off to a good start, she's ready to add another animal resident—this time it's a pig! Farmer Sue will also greet her pig, Hamlet, every morning!




```kotlin
class Pig(val name: String, val excitementLevel: Int) {
    fun speak() {
        repeat(excitementLevel) {
            println("Oink!")
        }
    }
}
```

*Listing 12.3 - Adding a* **`Pig`** *class.*

This looks very similar to the **`Chicken`** class. It also has a **`name`** property and a **`speak()`** function, but it doesn't have a **`numberOfEggs`** property. Instead, it has an **`excitementLevel`** property that determines how many "oink" sounds it makes.

We can update the code so that Sue greets both the chicken and the pig, but when we do that, we'll get a compile-time error.

Well, that makes sense, of course. The **`greet()`** function takes a **`Chicken`**, not a **`Pig`**.

```kotlin
val sue = Farmer("Sue")
val henrietta = Chicken("Henrietta")
val hamlet = Pig("Hamlet", 1)

sue.greet(henrietta)
sue.greet(hamlet)
```

*Listing 12.4 - **Error:** Type mismatch: Required Chicken. Found Pig.*

```
class Farmer(val name: String) {
    fun greet(chicken: Chicken) {
        println("Good morning, ${chicken.name}!")
        chicken.speak()
    }
}
```

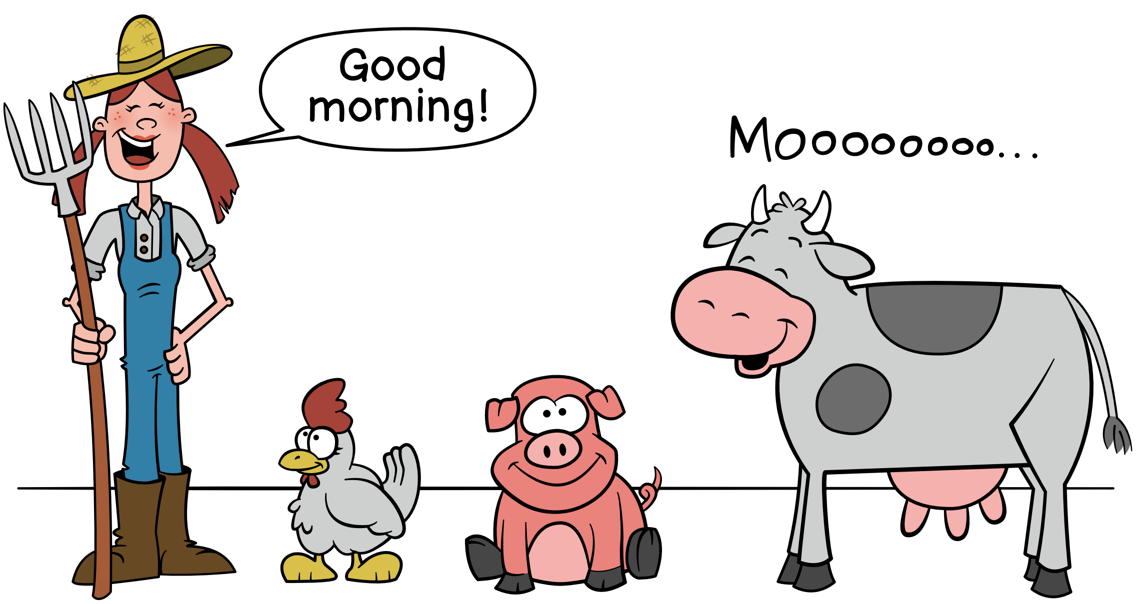
This parameter is a Chicken, not a Pig!

To remedy this, we can add a new function that takes a **`Pig`**. We can still name the new function **`greet()`**, but instead of accepting a **`Chicken`**, this one will accept a **`Pig`**. When we create a function that has the same name as another function but different parameter types, it's called **overloading** the function. Let's create an overload for **`greet()`** that accepts a **`Pig`** object.

```
class Farmer(val name: String) {
    fun greet(chicken: Chicken) {
        println("Good morning, ${chicken.name}!")
        chicken.speak()
    }

    fun greet(pig: Pig) {
        println("Good morning, ${pig.name}!")
        pig.speak()
    }
}
```

*Listing 12.5 - Adding a* **`greet(pig)`** *function—which is very similar to* **`greet(chicken)`**.

With this update, Listing 12.4 now compiles and runs as expected. Now that Sue's farm is doing great with a chicken and pig, she's ready to add a cow! As with the other animals, she greets her cow, Dairy Godmother, every morning, and hears a "Moo" in response!



Let's create a class for a Cow, which will include a **`name`** property and a **`speak()`** function, just like the other farm animals.

```
class Cow(val name: String) {
    fun speak() = println("Moo!")
}
```

*Listing 12.6 - A **`Cow`** class, which also has a **`name`** property and a **`speak()`** function.*

As with the pig, when we try to make Sue greet the cow, we get an error.

```
val sue = Farmer("Sue")
val henrietta = Chicken("Henrietta")
val hamlet = Pig("Hamlet", 1)
val dairyGodmother = Cow("Dairy Godmother")

sue.greet(henrietta)
sue.greet(hamlet)
sue.greet(dairyGodmother)
```

*Listing 12.7 - **Error:** None of the following functions can be called with the arguments supplied…*

Again, to fix this, we can add yet another overload to greet the cow.

```
class Farmer(val name: String) {
    fun greet(chicken: Chicken) {
        println("Good morning, ${chicken.name}!")
        chicken.speak()
    }

    fun greet(pig: Pig) {
        println("Good morning, ${pig.name}!")
        pig.speak()
    }

    fun greet(cow: Cow) {
        println("Good morning, ${cow.name}!")
        cow.speak()
    }
}
```

*Listing 12.8 - Adding a third **`greet()`** function. This one accepts a **`Cow`** object.*

Yikes! This is becoming unwieldy! Every time Sue adds a new kind of farm animal, we have to create *another* overload of the **`greet()`** function. That's a shame, because Farmer Sue has some big plans! She wants to add a donkey, a goat, and a llama! That means *even more* overloads…

All of these functions are so similar. In fact, the only difference is the name and type of the parameter.

These are all the same except for the name and type of the parameter:

```
fun greet(chicken: Chicken) {
    println("Good morning, ${chicken.name}!")
    chicken.speak()
}

fun greet(pig: Pig) {
    println("Good morning, ${pig.name}!")
    pig.speak()
}

fun greet(cow: Cow) {
    println("Good morning, ${cow.name}!")
    cow.speak()
}
```

Instead of adding a new function for each new farm animal, it'd be amazing if the **`greet()`** function could work with *any* kind of farm animal, whether it's a chicken, pig, cow, donkey, goat, llama, or anything else.

In other words, we want something like this.

```
class Farmer(val name: String) {
    fun greet(animal: FarmAnimal) {
        println("Good morning, ${animal.name}!")
        animal.speak()
    }
}
```

*Listing 12.9 - What we want: a function that can accept any kind of farm animal.*

Thankfully, Kotlin gives us an easy way to do this—with **interfaces**!

# Introducing Interfaces

When we look at the animal classes, we can see that they all look very similar—they all have a **`name`** property and a **`speak()`** function, as seen on the next page.

Any new animals that join Sue's farm will *also* have a *name* and a *sound* that they make when they speak to her. So, we can introduce a new type called **`FarmAnimal`**, and give it those same members—a **`name`** property and a **`speak()`** function.

Each of these has a speak() function...

... and a name property.

```
class Chicken(
    val name: String,
    var numberOfEggs: Int = 0
) {
    fun speak() = println("Cluck!")
}

class Pig(
    val name: String,
    val excitementLevel: Int) {
    fun speak() {
        repeat(excitementLevel) {
            println("Oink!")
        }
    }
}

class Cow(
    val name: String
) {
    fun speak() = println("Moo!")
}
```

As you might recall, so far, we've always created new types by using the **`class`** keyword. However, instead of introducing the **`FarmAnimal`** type with a *class*, we'll use an *interface*.

Like a class, an interface describes what properties and functions a type has. However, unlike a class, we don't have to actually *include* any function bodies! For example, we can create the **`FarmAnimal`** interface like this.

```
interface FarmAnimal {
    val name: String
    fun speak()
}
```

*Listing 12.10 - An interface that can represent any kind of farm animal.*

Notice that we didn't add any body to the **`speak()`** function here.

One difference between classes and interfaces, though, is that we can't instantiate an interface. For example, the following code won't work.

```
val donkey = FarmAnimal("Phyllis")
donkey.speak()
```

*Listing 12.11 - **Error:** Interface FarmAnimal does not have constructors.*

This makes sense—after all, since the **`FarmAnimal`** has no function body for **`speak()`**, what would we expect **`donkey.speak()`** to actually do?

So then, if interfaces cannot be *instantiated*, how can we *use* them? We *update our existing classes* to tell Kotlin that each of them is a **`FarmAnimal`** *in addition to* being a **`Chicken`**, **`Pig`**, or **`Cow`**.

To start with, let's update the **`Cow`** class, to mark it as a **`FarmAnimal`**.

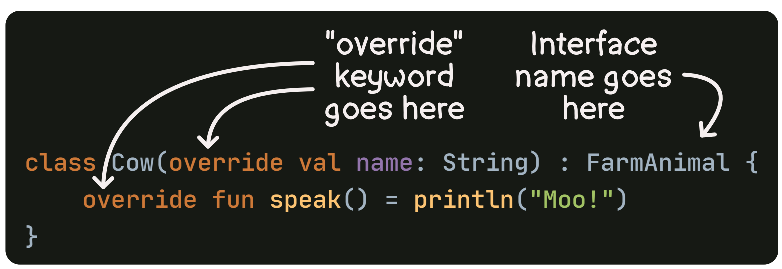
```
class Cow(override val name: String) : FarmAnimal {
    override fun speak() = println("Moo!")
}
```

*Listing 12.12 - Updating the **`Cow`** class so that it implements the **`FarmAnimal`** interface.*

When a class is marked with an interface like this, we say that the class **implements** the interface. In other words, the **`FarmAnimal`** interface says that each implementing class *must* include a **`name`** property and a **`speak()`** function, but says nothing about the sound the animal should make when **`speak()`** is called… just that the function must exist. The class, however, provides the *implementation*—that is, it has a **`speak()`** function that *does* have a function body.

A class that implements an interface needs to include a few things:

- It must declare that it implements the interface. To do this, add a colon and the name of the interface between the primary constructor and the opening brace of the class body.[1]
- It must add the **`override`** keyword to each property and function that the class implements from the interface. This keyword tells Kotlin that this property or function corresponds to the one from the interface.




Once we make these same changes to **`Chicken`** and **`Pig`**, we can proceed to remove all those **`greet()`** functions on the **`Farmer`** class, and replace them with a *single* function.

```
class Farmer(val name: String) {
    fun greet(animal: FarmAnimal) {
        println("Good morning, ${animal.name}!")
        animal.speak()
    }
}
```

*Listing 12.13 - Updating the **`greet()`** function to work with any implementations of **`FarmAnimal`**.*

[1] In cases where the class has no constructor or body, it'd be as easy as writing **`class Chicken : FarmAnimal`**.

Let's look closer at the relationship between classes and the interfaces that they implement, to understand why this works.

# Subtypes and Supertypes

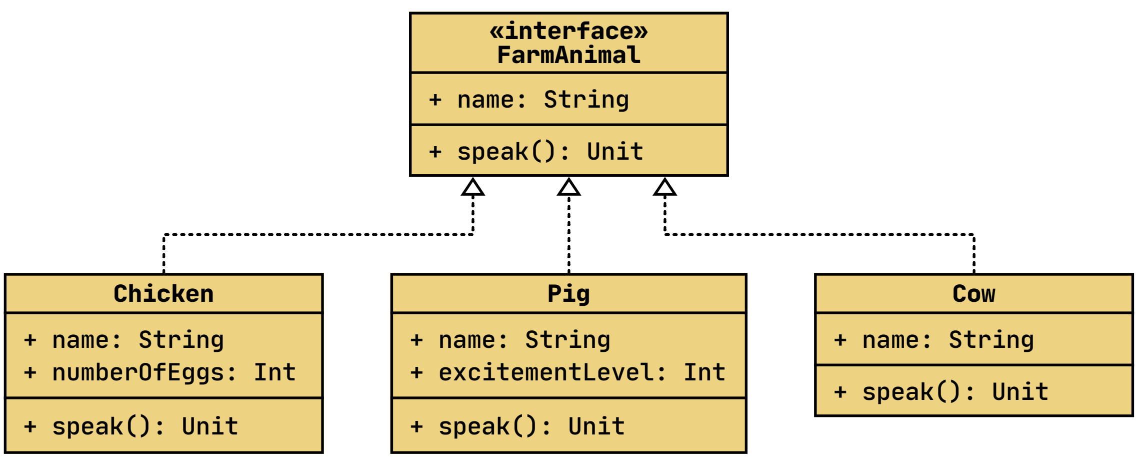
Any tangible, real-life object can usually be categorized in multiple ways. For example, if someone points to a chicken and asks you what it is, you might say "it's a *chicken*", or you might say, "it's a *farm animal*." One is more specific, and one is more general—but both are correct.

This idea of *specific* and *general* types also applies in Kotlin. Now that the **`Chicken`** class is marked as a **`FarmAnimal`**, all chicken objects are now *both* a **`Chicken`** (a more specific type) and **`FarmAnimal`** (a more general type).

When we're talking about types in Kotlin…

- A class that implements an interface is called a **subtype** of that interface, because the class is a more specific (or, "lower"—and therefore "sub") type.
- Conversely, an interface is called a **supertype** of a class that implements it, because an interface is a more general (or, "higher"—and therefore "super") type.

Back in Chapter 4, we created some UML diagrams to describe our classes. Here's a simple diagram showing that subtype/supertype relationship.




## Subtypes and Substitution

A specific type is suitable when someone requests a more general type. For example, if Farmer Sue asks you for a "farm animal" and you give her a chicken, she would be happy because a chicken is indeed a kind of farm animal. Alternatively, you could give her a cow or a pig. She would be happy with any of those, because each of those is a kind of farm animal.

Similarly, in Kotlin, *we can use a subtype anywhere that the code expects a supertype*. So for instance, if a variable, property, or function expects a **`FarmAnimal`**, we can give it a **`Chicken`**, **`Cow`**, or **`Pig`**. We already saw this with the **`greet(animal)`** function in Listing 12.13, but this also applies to variables.

To demonstrate this, we can explicitly specify the type of a variable as **`FarmAnimal`**, but assign it a **`Chicken`**.

```
val henrietta: FarmAnimal = Chicken("Henrietta")
```

*Listing 12.14 - Explicitly specifying a supertype.*

Similarly, we can create a list of **`FarmAnimal`** objects, and give it a **`Chicken`**, a **`Cow`**, and a **`Pig`**. Here's a revised version of Listing 12.7 that uses a **`List`**.

```
val sue = Farmer("Sue")

val animals: List<FarmAnimal> = listOf(
    Chicken("Henrietta"),
    Pig("Hamlet", 1),
    Cow("Dairy Godmother"),
)

animals.forEach { sue.greet(it) }
```

*Listing 12.15 - Using **`FarmAnimal`** in a **`List`** to put multiple implementations into a single collection.*

In both of these cases, we *declared* a type of **`FarmAnimal`**, but were able to provide a **`Chicken`**, **`Pig`**, or **`Cow`**, because each of those classes *implements* **`FarmAnimal`**.

However, when we assign an object with a more specific type (e.g., a **`Chicken`** object) to a more general variable or parameter (e.g., one whose type is a **`FarmAnimal`**), we lose the ability to do specific things with it. For example, the **`Chicken`** class has a **`numberOfEggs`** property. We can use this property just fine when the object is assigned to a **`Chicken`** variable.

```
val henrietta: Chicken = Chicken("Henrietta")
henrietta.numberOfEggs = 1
```

*Listing 12.16 - Explicitly specifying the subtype instead of the supertype.*

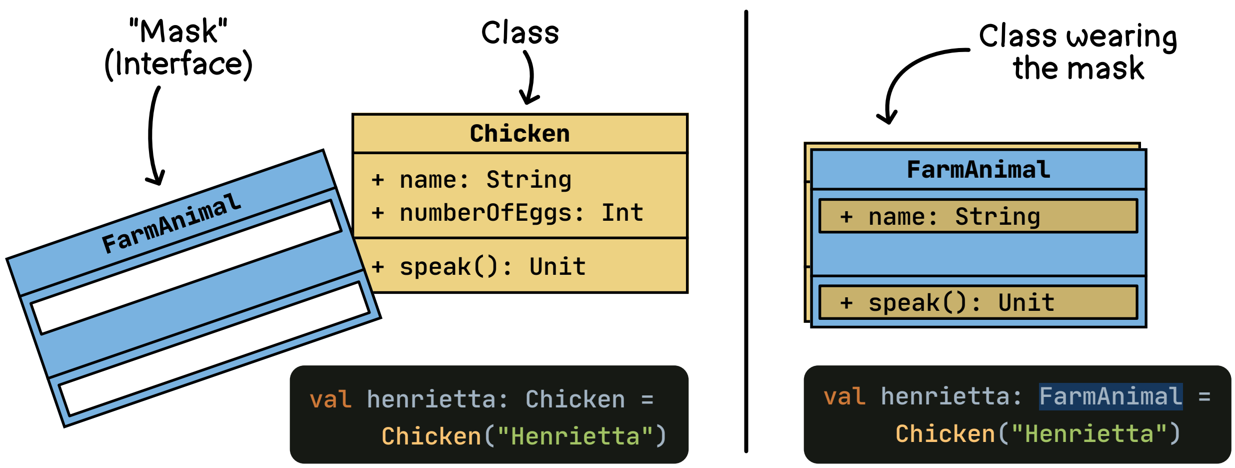
However, after simply changing the type of this variable from a **`Chicken`** to a **`FarmAnimal`**, we can't do anything with **`numberOfEggs`**.

```
val henrietta: FarmAnimal = Chicken("Henrietta")
henrietta.numberOfEggs = 1
```

*Listing 12.17 - **Error:** Unresolved reference: numberOfEggs.*

Why is that? Well, when an object of a *specific* type is assigned to a variable of a more *general* type, it's kind of like the object is wearing a mask. That mask hides the things that are declared in the specific type, but lets you see through to the properties and functions that are declared in the more general type.

For example, when assigning a **`Chicken`** object to a **`Chicken`** variable (as in Listing 12.16), the **`Chicken`** class isn't wearing a mask, so we can see *all* of its properties and functions. However, in Listing 12.17, the **`Chicken`** object is assigned to a **`FarmAnimal`** variable, so it's wearing a **`FarmAnimal`** mask, which only lets Kotlin see the things declared in the **`FarmAnimal`** interface—**`name`** and **`speak()`**.




Because it's wearing a mask, the properties and functions that are declared in **`FarmAnimal`** are visible, but any properties or functions declared in **`Chicken`** are hidden behind the mask, so they can't be seen. In some cases, this might prevent you from doing something you want to do. For example, if we update the **`greet()`** function so that Farmer Sue also says how many eggs she sees, we'll get an error at compile time.

```
val chicken: Chicken = Chicken("Henrietta")

class Farmer(val name: String) {
    fun greet(animal: FarmAnimal) {
        println("Hello, ${animal.name}!")
        println("You have ${animal.numberOfEggs} eggs today!")
        animal.speak()
    }
}
```

*Listing 12.18 - **Error:** Unresolved reference: numberOfEggs.*

It's good that Kotlin prevents us from doing this. After all, if we were to pass a **`Cow`** object instead of a **`Chicken`** object, the **`Cow`** would have no **`numberOfEggs`** property, so it wouldn't make sense to print out a line about eggs at all!

So, how can we get Kotlin to print the line about eggs *only* when the animal actually *is* a Chicken? To do that, we need the **`animal`** object to cast aside its mask!

# Casting

If you want to use a property or function that's declared on a subtype, *we have to tell the object to take off that mask first*. Changing the type, such as from `FarmAnimal` to `Chicken`, is called **casting**. There are a few ways to do this.

## Smart Casts

One common way to cast the type is to use a conditional with the `is` keyword, like this.

```
fun greet(animal: FarmAnimal) {
    println("Hello, ${animal.name}!")
    if (animal is Chicken) {
        println("I see you have ${animal.numberOfEggs} eggs today!")
    }
    animal.speak()
}
```

*Listing 12.19 - Using an `if` conditional with `is` to perform a smart cast.*

Now, *inside* the body of that conditional, the type of `animal` becomes `Chicken`. But outside of that body, it's still a `FarmAnimal`.

```
fun greet(animal: FarmAnimal) {
    println("Hello, ${animal.name}!")     Type of animal is
                                          FarmAnimal here
    if (animal is Chicken) {
        println("I see you have ${animal.numberOfEggs} eggs today!")     Type of animal
                                                                         is Chicken here
    }
    animal.speak()     Type of animal is
                       FarmAnimal again here
}
```

This is called a **smart cast**. If this looks familiar, it's because we already saw a smart cast in Chapter 6 when we looked at Kotlin's null-safety features. It's the same thing here, but instead of casting from a nullable to a non-nullable type, we're casting from a `FarmAnimal` to a `Chicken`.

Smart casts can only be used when Kotlin can be *certain* that the value won't change between the conditional and the expression where it's used. For example, in the code above, it's not possible for the value of `animal` to be reassigned, so Kotlin knows it's safe to use a smart cast here.

However, in other situations, it's entirely possible for the value to change after the conditional was evaluated. For example, Kotlin won't smart cast a `var` property of a class, because it's possible that other code might be running at the same time, and that code could reassign a new value to that property. So far, we haven't written any code that runs concurrently like that, but we'll see that in Chapter 20 when we look at coroutines.

## Explicit Casts

Smart casts are an easy way to cast a type, but we can also cast them explicitly. To do this, use the **`as`** keyword. Here's how that looks.

```
fun greet(animal: FarmAnimal) {
    println("Hello, ${animal.name}!")

    val chicken: Chicken = animal as Chicken
    println("I see you have ${chicken.numberOfEggs} eggs today!")

    animal.speak()
}
```

*Listing 12.20 - Explicitly casting to a* **`Chicken`**. *This is an 'unsafe cast'.*

The problem with this code is that if **`animal`** is *not* actually a **`Chicken`**—for example, if we called **`greet()`** with a **`Cow`**, then we'll get an error at runtime. That's why this is sometimes called an **unsafe cast**.

Alternatively, we can use the **`as?`** keyword (with the question mark), which is called a **safe cast**. Here's how that looks.

```
fun greet(animal: FarmAnimal) {
    println("Hello, ${animal.name}!")

    val chicken: Chicken? = animal as? Chicken
    chicken?.let { println("I see you have ${it.numberOfEggs} eggs today!") }

    animal.speak()
}
```

*Listing 12.21 - An explicit safe cast.*

The **`as?`** operator will *try* to cast the object to the specified type. It will evaluate to one of two things:

- If that object actually *is* that specified type, then it evaluates to that object.
- Otherwise, it evaluates to **`null`**.

In the code above, if **`greet()`** is called with a **`Chicken`** object, then **`chicken`** would be the same object instance as **`animal`**, but would have a compile-time type of **`Chicken?`**. In other words, it took off the mask… but we still have a nullable type to deal with. On the other hand, if **`greet()`** is called with a **`Cow`** object, then the **`chicken`** variable would be **`null`**.

Keep in mind that because **`as?`** evaluates to a nullable type, you've got to use null-safety tooling in order to deal with the null. For example, in Listing 12.21, we used a scope function for a null check.

A smart cast tends to be the more elegant approach in many cases, so if you find yourself needing to do a cast, that's a great place to start. Consider using **`as`** or **`as?`** only if it fits the situation well.

### Best Practice: Careful with Casting

Many developers prefer to avoid casting when possible, because it can make things harder to manage later.

For example, in Listing 12.13, the **`greet()`** function only knew about the **`FarmAnimal`** interface, but didn't need to know anything about its subtypes. This was nice because changes you make to the **`Chicken`** class wouldn't require you to make changes to the **`greet()`** function.

In Listing 12.21, though, a change to the **`Chicken`** class might require a change to the **`greet()`** function—such as if **`numberOfEggs`** were to be renamed.

## Multiple Interfaces

It's possible for a class to implement more than one interface. To demonstrate this, let's split up the **`FarmAnimal`** interface into two separate interfaces—one for the **`speak()`** function and one for the **`name`** property.

```
interface Speaker {
    fun speak()
}

interface Named {
    val name: String
}
```

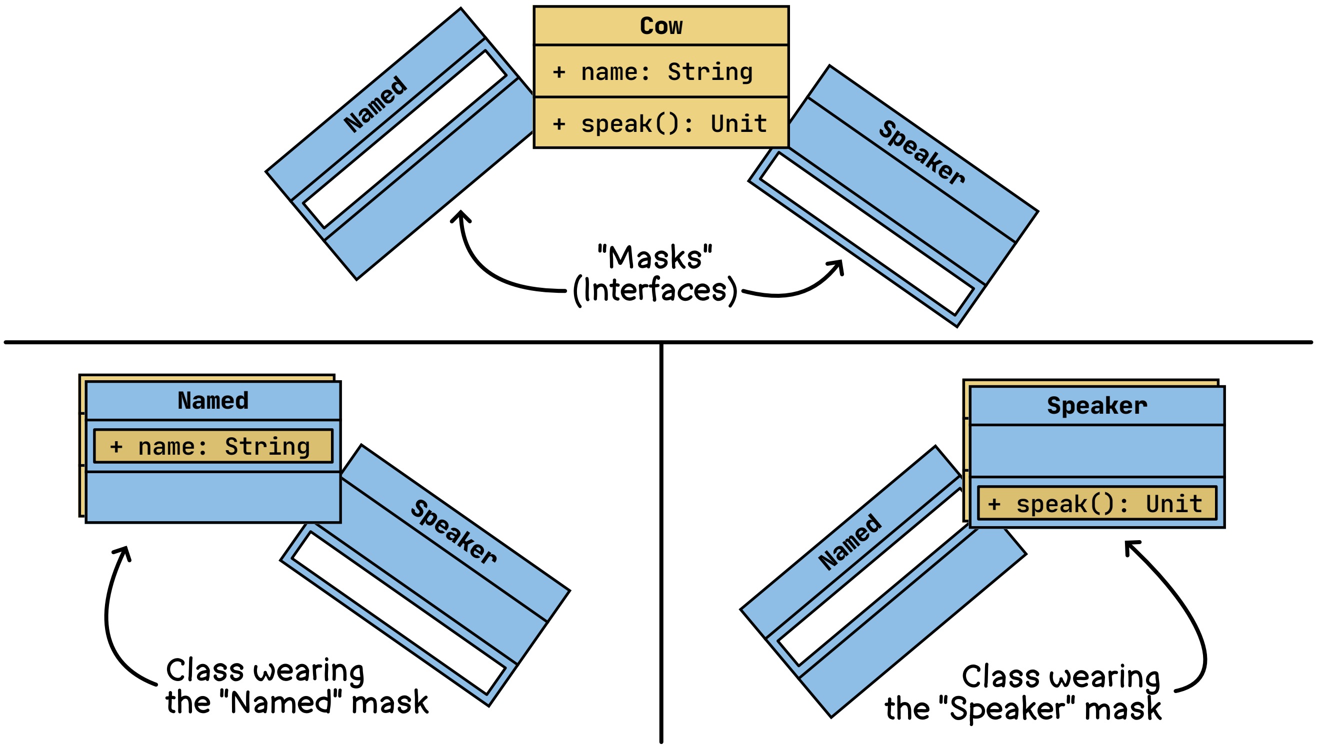
*Listing 12.22 - Two interfaces, split out from the* **`FarmAnimal`** *interface.*

To update the classes so that they implement both of these interfaces, we can simply separate the names of the interfaces with a comma, like this.

```
class Cow(override val name: String) : Speaker, Named {
    override fun speak() = println("Moo!")
}
```

*Listing 12.23 - A class that implements multiple interfaces.*

When we split things up into multiple interfaces like this, it's as if we're creating multiple "masks", each of which exposes only a small part of the class.




This makes it possible to use the type in a broader variety of situations. For example, imagine collecting a roster of everyone on the farm, including Farmer Sue. The `Farmer` class already has a `name` property, so we can easily update it to implement the `Named` interface.

```
class Farmer(override val name: String) : Named {
    // (eliding the class body for now)
}
```

*Listing 12.24 - Updating the `Farmer` class so that it implements the `Named` interface.*

With that change, now we can collect a list of *everyone* on the farm!

```
val roster: List<Named> = listOf(
    Farmer("Sue"),
    Chicken("Henrietta"),
    Pig("Hamlet", 1),
    Cow("Dairy Godmother")
)
```

*Listing 12.25 - Creating a list of `Named` objects, including both the farmer and the animals.*

However, by splitting the `FarmAnimal` interface into `Speaker` and `Named` interfaces, we've done away with the `FarmAnimal` interface. That means the `greet()` function doesn't work any more.

```
class Farmer(override val name: String) : Named {
    fun greet(animal: FarmAnimal) {
        println("Good morning, ${animal.name}!")
        animal.speak()
    }
}
```

*Listing 12.26 - **Error:** Unresolved reference: FarmAnimal.*

Let's fix that next!

# Interface Inheritance

In order to get the `greet()` function to work again, one simple solution would be to reintroduce the `FarmAnimal` interface, in addition to the `Speaker` and `Named` interfaces. In this case, the `speak()` function would be duplicated across `FarmAnimal` and `Speaker`, and the `name` property would be duplicated across `FarmAnimal` and `Named`.

```
interface Speaker {
    fun speak()
}

interface Named {
    val name: String
}

interface FarmAnimal {
    val name: String
    fun speak()
}
```

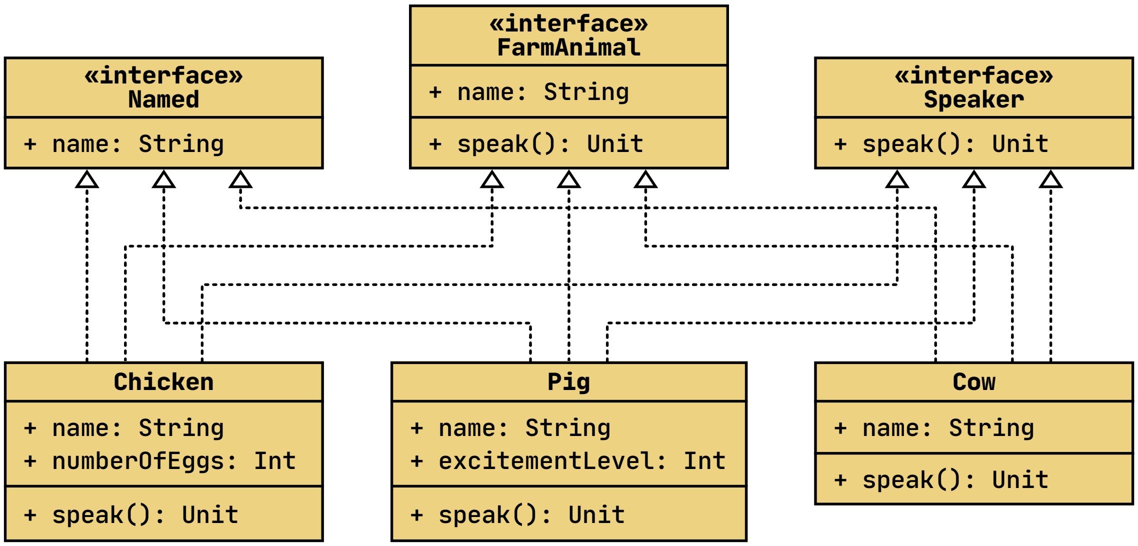
*Listing 12.27 - Duplicating the `Speaker` and `Named` interfaces in `FarmAnimal`.*

And after doing that, we'd need to update the classes so that they implement *all three* of these interfaces. For example, here's what it would look like for `Cow` to implement the `Speaker`, `Named`, and `FarmAnimal` interfaces.

```
class Cow(override val name: String) : Speaker, Named, FarmAnimal {
    override fun speak() = println("Moo!")
}
```

*Listing 12.28 - Implementing three interfaces in one class.*

This results in a pretty wild UML diagram, as seen on the next page.




Wow—there are lots of lines going everywhere! When a diagram is this confusing to look at, it usually means there's room for improvement in our code. Although this three-interface approach works, Kotlin gives us a more concise way to do this: an interface can **inherit** from other interfaces.[1]

When this happens, it *automatically includes* all of the properties and functions from the interfaces that it inherits from. For example, we can update the code from Listing 12.27 so that `FarmAnimal` inherits from both the `Speaker` and `Named` interfaces, like this.[2]

```
interface Speaker {
    fun speak()
}

interface Named {
    val name: String
}

interface FarmAnimal : Speaker, Named
```

*Listing 12.29 - Interface extension.*

As in Listing 12.27, a class that implements this `FarmAnimal` interface will still need to include a `name` property and a `speak()` function.

However, by inheriting from the `Speaker` and `Named` interfaces, `FarmAnimal` is now a subtype of them! This means that every `FarmAnimal` is also a `Speaker` and a `Named`. Now we can remove the `Speaker` and `Named` declarations from Listing 12.28 above, because they come along *automatically* as a part of `FarmAnimal`.

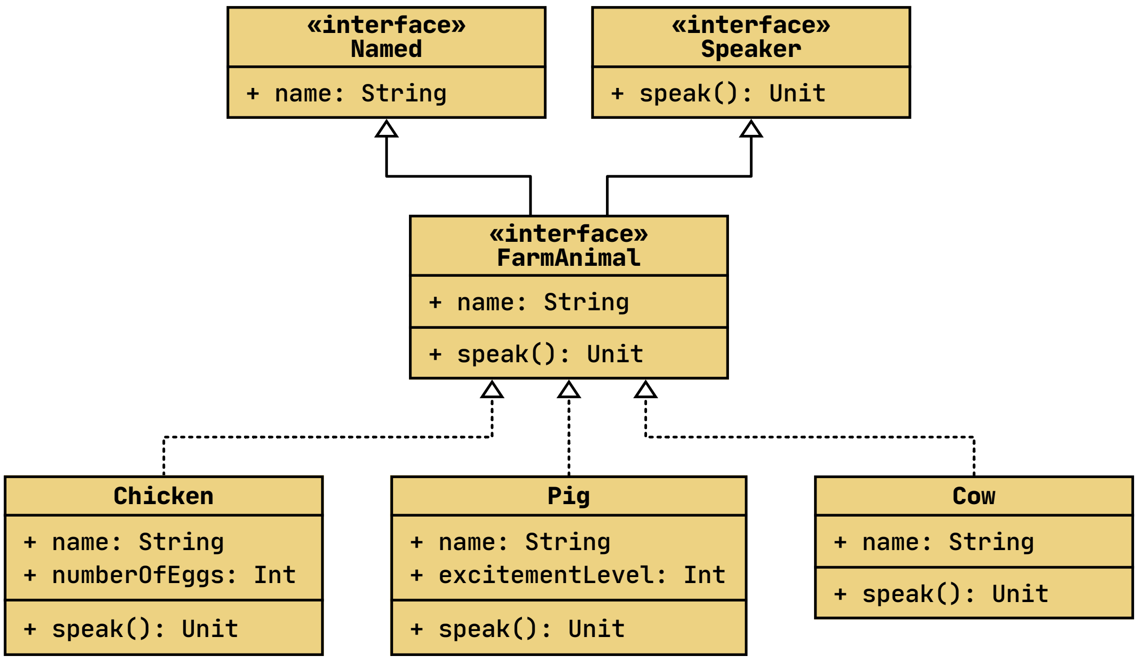
[1] Some languages call this *extending* another interface, but since this term could easily be confused with *extensions*, Kotlin developers prefer to call this *inheriting*. Inheritance applies to more than just interfaces, as we'll see in Chapter 14.

[2] The `FarmAnimal` interface here does not include a body, but often when you extend an interface, you would give it one. That way, `FarmAnimal` would inherit `name` and `speak()`, and then add some more properties or functions of its own.

```
class Cow(override val name: String) : FarmAnimal {
    override fun speak() = println("Moo!")
}
```

*Listing 12.30 - Declaring that* **Cow** *implements* **FarmAnimal**. *It's implied that it also implements* **Named** *and* **Speaker**, *because* **FarmAnimal** *extends those two interfaces.*

Even though this class only *declares* that it's a **FarmAnimal**, it's also still a **Named** and **Speaker** as well. The result is a UML diagram that looks like this.[1]




This diagram looks much better! Now these classes can be used in a lot of situations! For example, because **Cow** is a subtype of **FarmAnimal**, **Named**, and **Speaker**, a **Cow** object can be sent as an argument to any of the following functions.

```
fun milk(cow: Cow) = // ...
fun feed(animal: FarmAnimal) = // ...
fun introduce(name: Named) = // ...
fun listenTo(speaker: Speaker) = // ...
```

*Listing 12.31 - A* **Cow** *object can be used wherever a* **Cow**, **FarmAnimal**, **Named**, *or* **Speaker** *type is accepted.*

# Default Implementations

Most of the time, interfaces themselves do not contain any code—they don't usually include function bodies. However, they *can* actually include a function body, in order to provide a **default implementation**. This

[1] When following strict UML conventions, the **name** and **speak()** members wouldn't appear in the box for the **FarmAnimal** interface, because the arrows from **FarmAnimal** to **Named** and **Speaker** would imply their presence. They're explicitly included here for clarity.

default implementation will be used if the class doesn't provide its own implementation of that function. For example, let's update the **`Speaker`** interface so that it has a default implementation of the **`speak()`** function.

```
interface Speaker {
    fun speak() {
        println("...")
    }
}
```

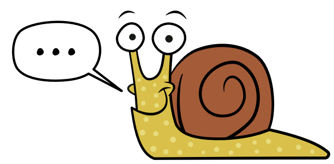
*Listing 12.32 - A default implementation in an interface.*

Now, we can create a new class that implements the **`FarmAnimal`** interface, but omits the **`speak()`** function!

```
class Snail(override val name: String) : FarmAnimal
```

*Listing 12.33 - A class that uses the default implementation for the **`speak()`** function.*

This **`Snail`** class has no class body, let alone a **`speak()`** function. However, we can still call the **`speak()`** function on a **`Snail`**, and when we do that, it'll print **`"..."`**— suggesting that the snail doesn't say much!




```
val snail = Snail("Slick")
snail.speak() // prints "..."
```

*Listing 12.34 - Calling the default implementation of **`speak()`**.*

We can also provide a default implementation for properties, but we can't just directly assign a value. For example, this won't work.

```
interface Named {
    val name: String = "No name"
}
```

*Listing 12.35 - **Error:** Property initializers are not allowed in interfaces.*

Instead, we can create a **getter** for the property. Some programming languages call this a *computed property*. We briefly saw a getter like this back in Chapter 10 when we created an extension property.

```
interface Named {
    val name: String get() = "No name"
}
```

*Listing 12.36 - A property getter.*

A getter is essentially an underlying function that is called whenever we get the property's value. So when we do **`println(something.name)`**, it calls that **`get()`** function and evaluates to the result of that function. In the code above, we're simply returning the value, **`"No name"`**.

Now that `FarmAnimal` has a default implementation for *both* `name` and `speak()`, we can create a class that implements the interface, but has no properties or functions at all.

```
class UnknownAnimal : FarmAnimal

val unknown = UnknownAnimal()
```

*Listing 12.37 - A class that implements `FarmAnimal`, using the default implementation for both `name` and `speak()`.*

Default implementations can be especially helpful when adding a new property or function to an existing interface. For example, if we were to add a new `nickname` property to the `FarmAnimal` interface, then the `Chicken`, `Pig`, and `Cow` classes would *all* need to be updated to have that new property, or else we'd get a compile-time error.

However, if the `FarmAnimal` interface had a default implementation for that property (for example, it could be set to `null` by default), then the code would compile successfully, even with no other changes to the classes. Then, if cows were the *only* ones who ever had nicknames, we could implement that property *only* in the Cow class.

# Summary

Well, Sue's farm is now in great shape! As she adds more and more animals to the farm, she'll be able to greet them all with ease. This chapter introduced the concept of an interface, and covered these topics:

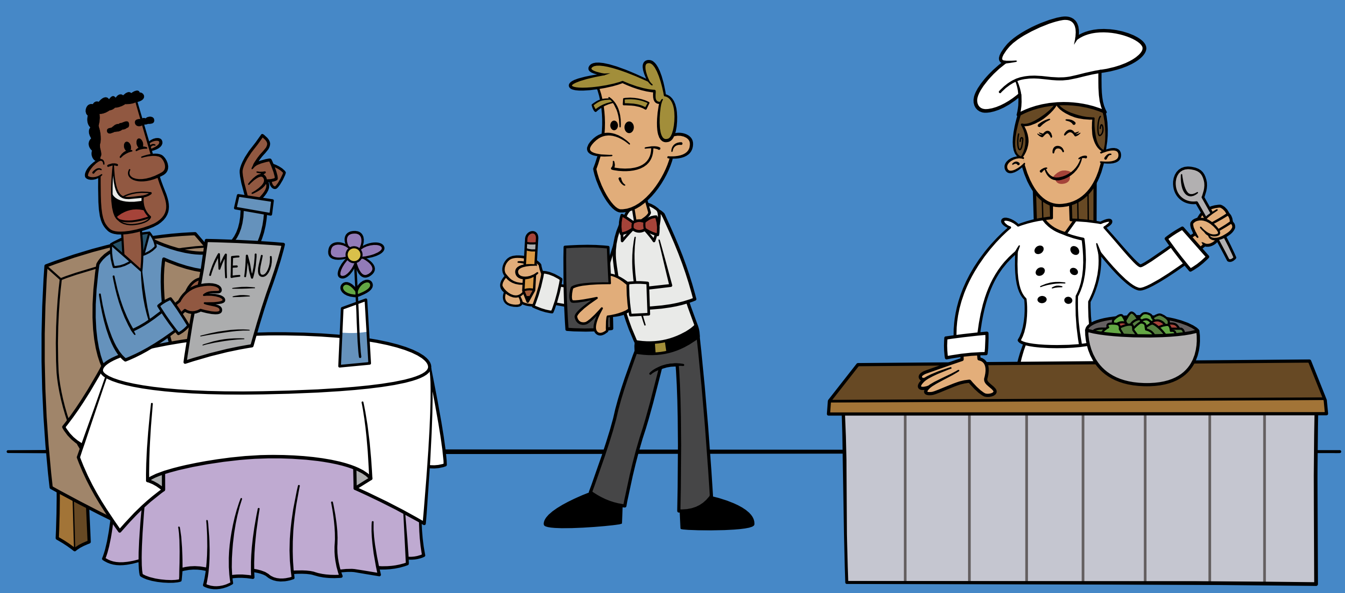
- Subtypes and supertypes.
- Casting types with smart casts, unsafe casts, and safe casts.
- Implementing multiple interfaces.
- Inheriting from an interface.
- Default implementations.

In the next chapter, we'll see how we can use interfaces to easily delegate function and property calls to other objects. Let's plow ahead!

Kotlin: An Illustrated Guide

Chapter 13

# Introduction to Class Delegation



# Don’t duplicate those functions!

Back in Chapter 2, we introduced functions as a way to prevent us from duplicating *expressions*. Once we start working with classes, we might notice that it’s also possible to end up duplicating our *functions*.

There are lots of ways to reuse our functions instead of duplicating them. In this chapter, we’ll see how we can use interfaces with Kotlin’s *class delegation* feature to reuse the code from our functions and properties.

# Roger's Dinner Out

Roger has had a busy week! He finally finished up a major project at work, so instead of cooking at home, he decided to treat himself to a nice dinner at one of his favorite restaurants. As he settles into his seat and glances over the menu, the waiter approaches with a welcoming smile.

"Can I start you off with something to drink, sir?"

"I'd like a soda, please," says Roger.

"One moment, sir." The waiter walks back to a counter in the kitchen, fills a glass of soda, and sets it down on the table.

"Are you ready to order your meal, sir?"

Roger replies, "Yes, I'd like the salmon on rice, please."

"Very well," says the waiter. He walks back to the kitchen again.

This time, though, he doesn't prepare the order himself. Instead, he hands it off to the chef, who skillfully prepares the delicious dinner. Once it's ready, the chef hands the meal to the waiter, who returns and places it on the table for Roger.

# Delegation in Restaurants and Code

As this story shows, sometimes a waiter can fulfill an order without involving the chef—such as when Roger ordered his beverage. But in other cases, such as when Roger ordered an entrée, the waiter has to hand off the order to the *chef* to fulfill.

Similarly, in Kotlin, sometimes an object is fully capable of fulfilling a request (such as a function call) on its own, and in other cases, it might need to hand off the request to *another object*.

Whether this happens in real life or in Kotlin, it's called **delegation**.

## By the Way: Delegation vs. Forwarding

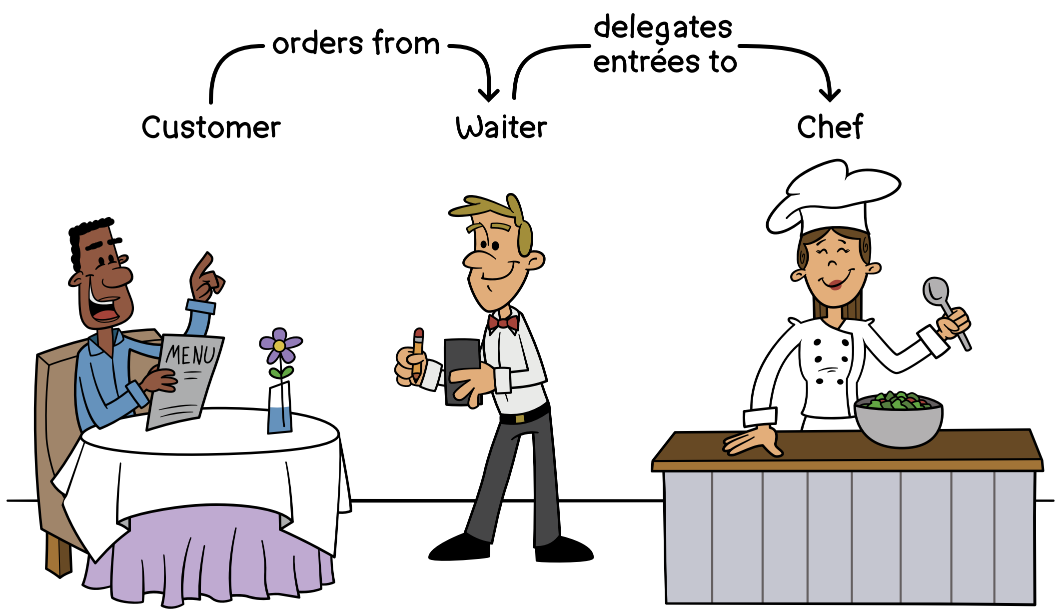
Technically, what you're going to see in this chapter is more precisely known in the broader programming community as "forwarding" rather than "delegation".

However, in the Kotlin world, it's always referred to as *delegation*, so we'll continue to use that term here.

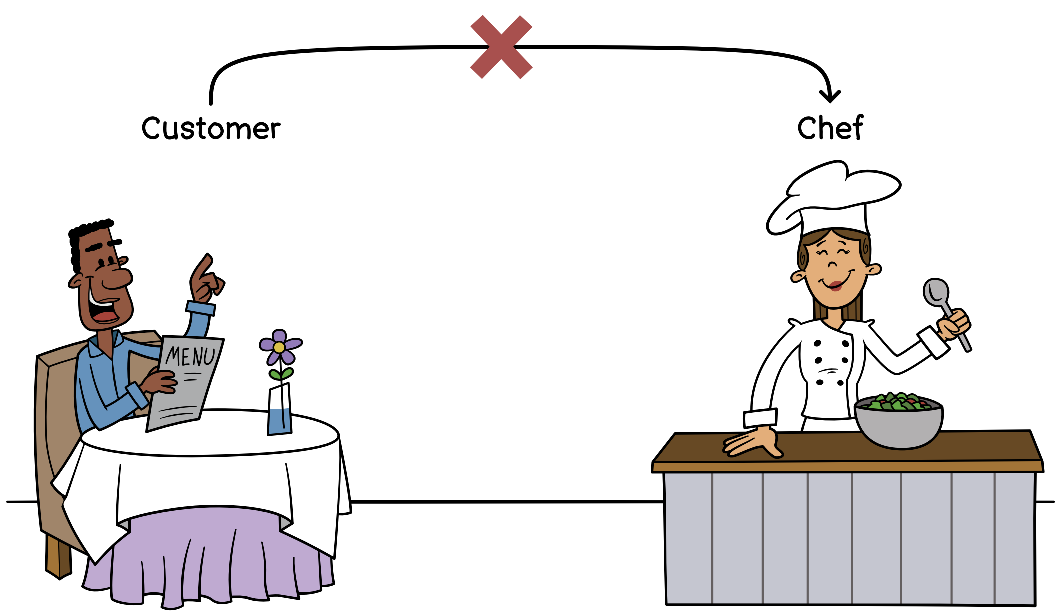
# Manual Delegation

Let's review the relationship between the customer, the waiter, and the chef.

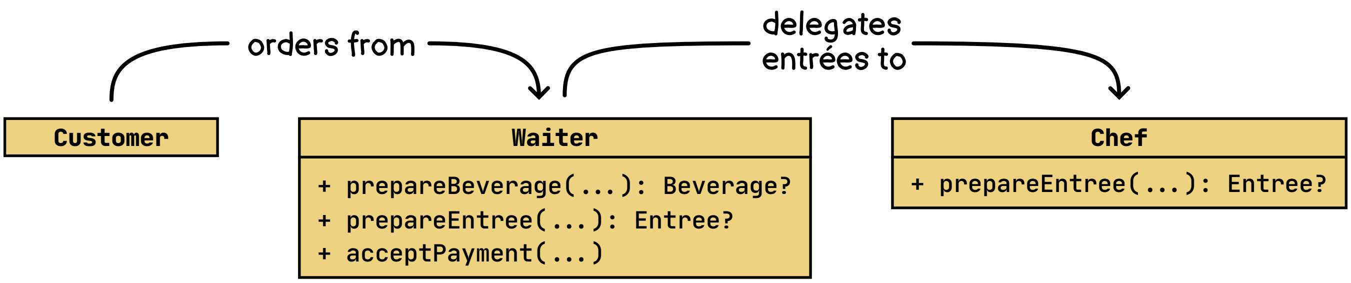
1. The *customer* places an order with the *waiter*.
2. When the order is for an entrée, the *waiter* delegates the entrée preparation to the *chef*.




Notice that the customers never interact with the chef *directly*—they only ever interact with the *waiter*, who will interact with the chef on the customers' behalf.




We can model this customer-waiter-chef relationship in Kotlin. To get started, let's replace the *drawings* above with *boxes*, which will roughly convert our illustration into a simple UML class diagram.




We can use the diagram above as the basis for our Kotlin code. Let's create classes to represent the waiter and the chef. We'll also need to represent the beverage and entrée options, so we can create some simple enum classes for those.

```
class Chef {
    fun prepareEntree(name: String): Entree? = when (name) {
        "Tossed Salad"    -> Entree.TOSSED_SALAD
        "Salmon on Rice" -> Entree.SALMON_ON_RICE
        else              -> null
    }
}

class Waiter(private val chef: Chef) {
    // The waiter can prepare a beverage by himself...
    fun prepareBeverage(name: String): Beverage? = when (name) {
            "Water" -> Beverage.WATER
            "Soda"  -> Beverage.SODA
            else    -> null
        }

    // ... but needs the chef to prepare an entree
    fun prepareEntree(name: String): Entree? = chef.prepareEntree(name)

    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")
}

enum class Entree { TOSSED_SALAD, SALMON_ON_RICE }
enum class Beverage { WATER, SODA }
```

*Listing 13.1 - Modeling out the* `Chef` *and* `Waiter` *classes.*

In the code above, the `prepareEntree()` function in the `Waiter` class simply calls the same function on the `chef` object, sending along the same `name` argument that it received. This is manual delegation.

Note that the word **delegate** can be either a noun or a verb, with a slight difference in pronunciation. In the listing above, the `chef` object here is called a **delegate** (noun), because the `Waiter` **delegates** (verb) the `prepareEntree()` call to it.

With this, we have classes for both the waiter and the chef. However, we won't create a separate class for the customer. Instead, the code in the next listing will act like a customer, calling functions on a `Waiter` instance.

```
val waiter = Waiter(Chef())

val beverage = waiter.prepareBeverage("Soda")
val entree = waiter.prepareEntree("Salmon on Rice")
```

*Listing 13.2 - Simulating the behavior of a customer.*

With this, we've established a simple, manual delegation relationship between the `Waiter` and the `Chef`, and by calling `prepareEntree()` on the `waiter`, we can see it call through to the `Chef` instance. As we'll see in a moment, delegation can be even easier than this!

Before we move on, though, you might have noticed that both `Waiter` and `Chef` have a function named `prepareEntree()`, and those two functions have the *same* parameter types and return type.

```
class Chef {
    fun prepareEntree(name: String): Entree? = when (name) {
        "Caesar Salad"   -> Entree.CAESAR_SALAD
        "Salmon on Rice" -> Entree.SALMON_ON_RICE
        else             -> null
    }
}

class Waiter(private val chef: Chef) {
    // The waiter can prepare a beverage by himself...
    fun prepareBeverage(name: String): Beverage? = when (name) {
        "Water" -> Beverage.WATER
        "Soda"  -> Beverage.SODA
        else    -> null
    }

    // ... but needs the chef to prepare an entree
    fun prepareEntree(name: String): Entree? = chef.prepareEntree(name)

    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")
}
```

same function name,
parameter, and
return type

As we saw in the last chapter, when this happens, we can create an interface.

Let's update our code from Listing 13.1 so that `Waiter` and `Chef` both implement the same interface. We'll name the new interface `KitchenService`, and give it the `prepareEntree()` function.

Remember, when we implement the interface, we'll also need to mark the `prepareEntree()` function with the `override` keyword in those two classes.

```
interface KitchenService {
    fun prepareEntree(name: String): Entree?
}

class Chef : KitchenService {
    override fun prepareEntree(name: String): Entree? = when (name) {
        "Tossed Salad"    -> Entree.TOSSED_SALAD
        "Salmon on Rice" -> Entree.SALMON_ON_RICE
        else             -> null
    }
}

class Waiter(private val chef: Chef) : KitchenService {
    fun prepareBeverage(name: String): Beverage? = when (name) {
            "Water" -> Beverage.WATER
            "Soda"  -> Beverage.SODA
            else    -> null
        }

    override fun prepareEntree(name: String): Entree? = chef.prepareEntree(name)
    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")
}
```

*Listing 13.3 - Updating* **`Chef`** *and* **`Waiter`** *to implement a new* **`KitchenService`** *interface.*

Great! We've now got a delegation relationship between the **`Waiter`** and the **`Chef`**, plus we've created an interface for **`prepareEntree()`** function that they both share.

## Delegating More Function Calls

Now, writing one function to manually call **`chef.prepareEntree()`** isn't too bad, but there are plenty of other occasions when the waiter might delegate to the chef. For example, the waiter might need to get a list of the chef's specials for the day, prepare an appetizer, prepare a dessert, or send along the customer's compliments to the chef.

It's easy to update the interface to include these things.

```
interface KitchenService {
    val specials: List<String>
    fun prepareEntree(name: String): Entree?
    fun prepareAppetizer(name: String): Appetizer?
    fun prepareDessert(name: String): Dessert?
    fun receiveCompliment(message: String)
}
```

*Listing 13.4 - Adding more members to the* **`KitchenService`** *interface.*

However, we also have to update the `Chef` and `Waiter` classes to *implement* the new property and functions. As for how the `Chef` class might implement those functions… we can leave that to our imaginations. We can easily see how this affects the `Waiter` class, though.

```kotlin
class Waiter(private val chef: Chef) : KitchenService {
    // These first two functions are the same as before
    fun prepareBeverage(name: String): Beverage? = when (name) { /* ... */ }
    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")

    // Manually delegating to the chef for all of these things:
    override val specials: List<String> get() = chef.specials
    override fun prepareEntree(name: String) = chef.prepareEntree(name)
    override fun prepareAppetizer(name: String) = chef.prepareAppetizer(name)
    override fun prepareDessert(name: String) = chef.prepareDessert(name)
    override fun receiveCompliment(message: String) = chef.receiveCompliment(message)
}
```

*Listing 13.5 - Overriding the new properties and functions in the `Waiter` class.*

As more and more properties and functions are added to the `KitchenService` interface, manually delegating from the `Waiter` to the `Chef` becomes tedious to write, tedious to read, and makes it more likely that we could accidentally get something wrong.

When you look at `override` functions above, you'll notice a lot of repeated text in the code, including:

- The `"override fun"` keywords.
- The function name, which is repeated on both the left and right of each line.
- The parameter names, which are also repeated on the left and right of each line.

Code that has the same repeated pattern like this is called **boilerplate**.[1] Even using Kotlin's expression body functions, as we're doing here, the boilerplate is really starting to pile up.

```kotlin
override val specials: List<String> get() = chef.specials
override fun prepareEntree(name: String) = chef.prepareEntree(name)
override fun prepareAppetizer(name: String) = chef.prepareAppetizer(name)
override fun prepareDessert(name: String) = chef.prepareDessert(name)
override fun receiveCompliment(message: String) = chef.receiveCompliment(message)
```

Lots of boilerplate!

Thankfully, Kotlin makes it easy to do this kind of delegation, without having to write it all by hand!

[1] The term *boilerplate* comes from the old days of the printed newspaper industry, when publishing syndicates would send local newspapers stories on metal plates that were ready for them to print. Those metal plates looked like the plating used when producing steam boilers. Those stories were also often fluff articles that lacked original content, which is how the term got its meaning. ("boilerplate," Merriam-Webster.com Dictionary, https://www.merriam-webster.com/dictionary/boilerplate).

# Easy Delegation, the Kotlin Way

Instead of writing all of the boilerplate for delegation *manually*, we can just use Kotlin's **class delegation** feature. To do this, we just need to do two things.

1. Indicate which functions and properties to delegate.
2. Indicate which object they should be delegated to.

The functions and properties are specified by the name of the *interface* that contains them, and the delegate is specified using the `by` keyword. Once we do this, we can remove the manual delegation. For example, to delegate all of the properties and functions in `KitchenService` to the `chef` object, we can simply write this.

```kotlin
class Waiter(private val chef: Chef) : KitchenService by chef {
    fun prepareBeverage(name: String): Beverage? = when (name) { /* ... */ }
    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")
}
```

*Listing 13.6 - Automatically delegating to the* `chef` *object.*

Easy, right? This code works the same as Listing 13.5—it's just written differently. With this change, all of the properties and functions that were manually delegated to `chef` are *completely omitted* from the Waiter class body, but it's still delegating them!

The only functions remaining inside this class are `prepareBeverage()` and `acceptPayment()`—the two functions that `Waiter` handles himself.

In other words, when we look at this class, we can really focus on what's *unique* about the `Waiter` class instead of having to see everything that it delegates to `chef`.

By simply including `by chef`, Kotlin does a lot of work for us. When you look at the first line of Listing 13.6, you can read it like: "`Waiter` implements `KitchenService` `by` delegating to `chef`."

Illustrated, here's how it looks.

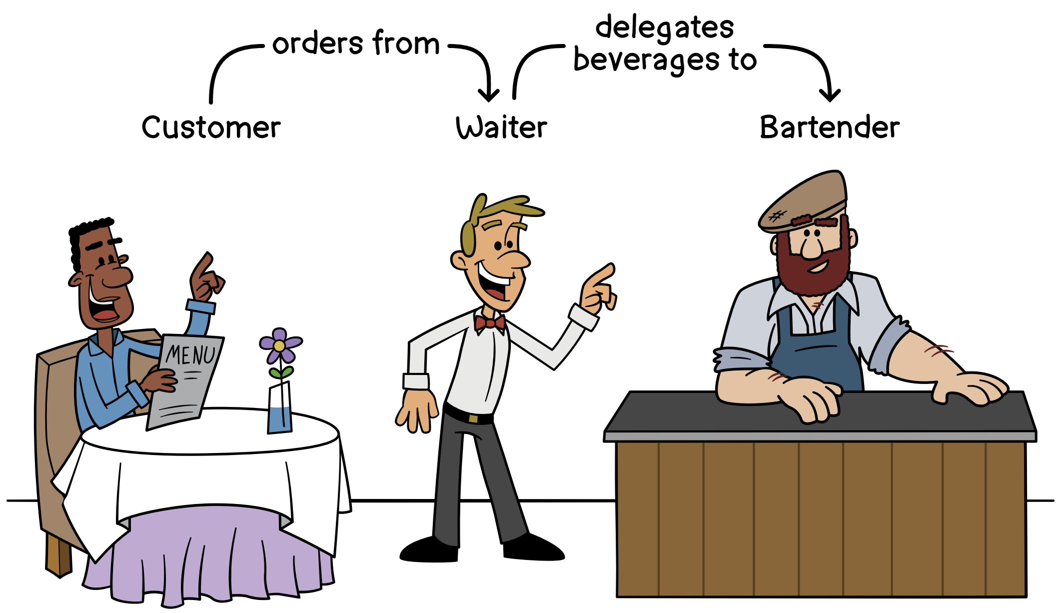
```
                implements                         delegating to
class Waiter(private val chef: Chef) : KitchenService by chef
```

## By the Way: Delegating to a Constructor Parameter

We *could* even remove `"private val"` from the `chef` constructor parameter. That would make it just a constructor parameter rather than a property. However, we're going to need it again later in this chapter, so let's leave it there for now.

# Multiple Delegates

Good news—the restaurant just opened up its new beverage bar, offering fancy drinks like peach iced tea and tea-lemonade. Instead of preparing the beverages himself, the waiter will now delegate beverage preparation to the *bartender*.




To start with, let's add a new interface and class for the bartender. We'll also update the **`Beverage`** enum class with the new beverage options.

```
interface BarService {
    fun prepareBeverage(name: String): Beverage?
}

class Bartender: BarService {
    override fun prepareBeverage(name: String): Beverage? = when (name) {
        "Water"        -> Beverage.WATER
        "Soda"         -> Beverage.SODA
        "Peach Tea"    -> Beverage.PEACH_ICED_TEA
        "Tea-Lemonade" -> Beverage.TEA_LEMONADE
        else           -> null
    }
}

enum class Beverage { WATER, SODA, PEACH_ICED_TEA, TEA_LEMONADE }
```

*Listing 13.7 - Adding an interface and class for the bartender.*

Now, we want the **`Waiter`** to delegate the beverage preparation to the **`Bartender`**. To start, let's add a **`bartender`** property to the **`Waiter`**, and manually delegate to it, just like we did previously with the **`chef`**.

```
class Waiter(
    private val chef: Chef,
    private val bartender: Bartender
) : KitchenService by chef, BarService {
    override fun prepareBeverage(name: String) = bartender.prepareBeverage(name)
    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")
}
```

*Listing 13.8 - Manually delegating to the* **`bartender`** *object.*

Here, we've got Kotlin *automatically* delegating everything in **`KitchenService`** to the **`chef`**, and we're *manually* delegating **`prepareBeverage()`** to the **`Bartender`**. This is fine, but Kotlin also allows us to use **`by`** to delegate to *more than one object at a time*, and it works just like you'd expect. Simply add **`"by bartender"`** after **`BarService`**, like this.

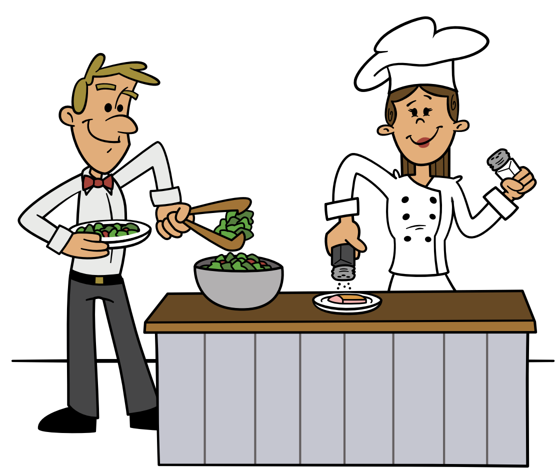
```
class Waiter(
    private val chef: Chef,
    private val bartender: Bartender
) : KitchenService by chef, BarService by bartender {
    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")
}
```

*Listing 13.9 - Automatically delegating to the* **`bartender`** *object.*

With this, the **`Waiter`** class now delegates to *two* different objects. As in Listing 13.8, its body only contains what's unique to the **`Waiter`** class. All of the delegation boilerplate is tucked away behind those simple **`by`** declarations!

# Overriding a Delegated Call

As it's getting later, the restaurant is getting crowded, and the chef is busy trying to prepare food for all of the customers. So, the chef says to the waiter, "The salad is easy to prepare. From now on, if you get an order for a tossed salad, just take care of it yourself. I'll still handle the fancy meals."



As we've seen, when we use Kotlin's class delegation, all of the properties and functions from the interface are automatically sent to the designated object.

However, we can also choose *not* to automatically delegate certain properties or functions from the interface.

Let's update our Kotlin code so that the **`Waiter`** can prepare the salad by himself. To do this, we can include the **`prepareEntree()`** function in **`Waiter`** again, and manually delegate it to the **`chef`** *only when needed*. Here's how that looks.

```
class Waiter(
    private val chef: Chef,
    private val bartender: Bartender
) : KitchenService by chef, BarService by bartender {
    override fun prepareEntree(name: String): Entree? =
        if (name == "Tossed Salad") Entree.TOSSED_SALAD else chef.prepareEntree(name)

    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")
}
```

*Listing 13.10 - Using both automatic and manual delegation with the* **`chef`** *object.*

When a function from **`KitchenService`** is included in the **`Waiter`** class, Kotlin will use that function instead of the automatically sending it to the delegate. However, we can still choose to manually delegate to it, as we're doing here in Listing 13.10. When the customer orders anything other than a tossed salad, we manually delegate to the **`chef`**.

So, we can combine Kotlin's class delegation *with* manual delegation.

# Managing Conflicts

When the meal is fantastic, sometimes the customer tells the waiter to send along his compliments to the chef. The **`KitchenService`** interface has a function named **`receiveCompliment()`**. So, when this function is called on a **`Waiter`** object, it's sent along to its **`chef`** object. Inside the **`Chef`** class, we can simply print out that the compliment was received, like this.

```
interface KitchenService {
    // ... disregarding other properties and functions ...
    fun receiveCompliment(message: String)
}

class Chef : KitchenService {
    // ... disregarding other properties and functions ...
    override fun receiveCompliment(message: String) =
        println("Chef received a compliment: $message")
}
```

*Listing 13.11 - Implementing* **`receiveCompliment()`** *inside the* **`Chef`** *class.*

And of course, calling this function on the **`waiter`** will send it along to the **`chef`**.

```kotlin
val waiter = Waiter(Chef(), Bartender())

val beverage = waiter.prepareBeverage("Water")
val entree = waiter.prepareEntree("Salmon on Rice")

waiter.receiveCompliment("The salmon entree was fantastic!")
```

*Listing 13.12 - Calling* **`receiveCompliment()`** *on the* **`waiter`** *object, which is forwarded to the* **`chef`**.

The chef isn't the only one who might receive a compliment, though. The bartender makes an excellent peach iced tea, and sometimes the customers want to send along their compliments to the bartender, too!

Let's update the **`BarService`** interface and the **`Bartender`** class so that he can also receive a compliment.

```kotlin
interface BarService {
    fun prepareBeverage(name: String): Beverage?
    fun receiveCompliment(message: String)
}

class Bartender: BarService {
    // ... disregarding other properties and functions ...
    override fun receiveCompliment(message: String) =
        println("Bartender received a compliment: $message")
}
```

*Listing 13.13 - Updating the* **`BarService`** *interface and* **`Bartender`** *class to receive a compliment.*

Now, *both* **`Chef`** and **`Bartender`** include a function named **`receiveCompliment()`**—and they both have the same parameter types and return type.

```kotlin
interface KitchenService {
    val specials: List<String>
    fun prepareEntree(name: String): Entree?
    fun prepareAppetizer(name: String): Appetizer?
    fun prepareDessert(name: String): Dessert?
    fun receiveCompliment(message: String)
}

interface BarService {
    fun prepareBeverage(name: String): Beverage
    fun receiveCompliment(message: String)
}
```

same function name, parameter, and return type

So, when our code calls **`waiter.receiveCompliment()`**, what should Kotlin do with it? Should it send the compliment to the **`chef`** object, or to the **`bartender`** object? Or maybe both?

It's up to you as the programmer to decide. In fact, in a situation like this, when we try to use class delegation for two interfaces that have the same property or function, we'll get a compiler error that looks like this.

> Class '`Waiter`' must override `public open fun receiveCompliment(message: String): Unit` defined in `Waiter` because it inherits many implementations of it.

To resolve this, we'll need to include this function in the `Waiter` class. For example, we could check to see if the `message` includes the word "entree" or "beverage", and manually delegate to the chef or bartender accordingly. Then, as a last resort, the waiter can receive the compliment himself.

```kotlin
class Waiter(
    private val chef: Chef,
    private val bartender: Bartender
) : KitchenService by chef, BarService by bartender {
    override fun receiveCompliment(message: String) = when {
        message.contains("entree")   -> chef.receiveCompliment(message)
        message.contains("beverage") -> bartender.receiveCompliment(message)
        else                         -> println("Waiter received compliment: $message")
    }

    override fun prepareEntree(name: String): Entree? =
        if (name == "Tossed Salad") Entree.TOSSED_SALAD else chef.prepareEntree(name)

    fun acceptPayment(money: Int) = println("Thank you for paying for your meal")
}
```

*Listing 13.14 - Manually delegating* `receiveCompliment()` *to either the* `chef` *or the* `bartender`*; or handling it directly.*

And now, the customer can send compliments to the chef, the bartender, or the waiter!

```kotlin
val waiter = Waiter(Chef(), Bartender())

waiter.receiveCompliment("The salmon entree was fantastic!")
waiter.receiveCompliment("The peach tea beverage was fantastic!")
waiter.receiveCompliment("The service was fantastic!")
```

*Listing 13.15 - Sending compliments to the* `chef`*, the* `bartender`*, and the* `waiter`*.*

```
Chef received a compliment: The salmon entree was fantastic!
Bartender received a compliment: The peach tea beverage was fantastic!
Waiter received compliment: The service was fantastic!
```

So far, we've used class delegation to easily forward property calls and function calls from a `waiter` object to the `chef` and `bartender` objects. Although waiters, chefs, and bartenders illustrate the concept of delegation with concrete examples, delegation is also often used for a different purpose—to share *general* code across multiple *specific* types. So before we wrap up this chapter, let's see how that works!

# Delegation for General and Specific Types

As we saw in the last chapter, interfaces often represent *general types* like **`FarmAnimal`**, and classes that implement interfaces often represent more *specific* types like **`Chicken`**, **`Pig`**, and **`Cow`**. In some cases, we might have some general code that we want to *share* among many different specific types.

For example, all farm animals will want to eat, although the particular food that they eat might be a little different depending on what kind of animal they are. In this next code listing, we have three farm animals, each implementing its own **`eat()`** function.

```
class Cow {
    fun eat() = println("Eating grass - munch, munch, munch!")
}

class Chicken {
    fun eat() = println("Eating bugs - munch, munch, munch!")
}

class Pig {
    fun eat() = println("Eating corn - munch, munch, munch!")
}

Cow().eat()     // Eating grass - munch, munch, munch!
Chicken().eat() // Eating bugs - munch, munch, munch!
Pig().eat()     // Eating corn - munch, munch, munch!
```

*Listing 13.16 - Three farm animals, all eating something different.*

You probably noticed some boilerplate code here again. In fact, other than their names, the only difference between each of these classes is the *food* in the string. The **`eat()`** function is *general*, and we can share it across these *specific* classes with delegation.

It's quick and easy, so let's start with a simple interface for someone who eats.

```
interface Eater {
    fun eat()
}
```

*Listing 13.17 - An interface for any object that can eat.*

Now let's implement this interface with a class that makes that *munching* sound.

```
class Muncher(private val food: String) : Eater {
    override fun eat() = println("Eating $food - munch, munch, munch!")
}
```

*Listing 13.18 - A class that implements the* `Eater` *interface, making a munching sound.*

By using class delegation, we can make it so that all of the animals *share* this implementation of the **`eat()`** function. Notice that there's a lot less repeated code now!

```
class Cow : Eater by Muncher("grass")
class Chicken : Eater by Muncher("bugs")
class Pig : Eater by Muncher("corn")

Cow().eat()     // Eating grass - munch, munch, munch!
Chicken().eat() // Eating bugs - munch, munch, munch!
Pig().eat()     // Eating corn - munch, munch, munch!
```

*Listing 13.19 - Using delegation so that all animals can use the same* `eat()` *function.*

As it turns out, the pigs on this farm like to scarf down their dinner much faster than the cows and chickens, who usually just graze. So instead of sharing the **`Muncher`** code with them, we can just implement the **`eat()`** function directly in **`Pig`**.

```
class Cow : Eater by Muncher("grass")
class Chicken : Eater by Muncher("bugs")
class Pig : Eater {
    override fun eat() = println("Scarfing down corn - NOM NOM NOM!!!")
}

Cow().eat()     // Eating grass - munch, munch, munch!
Chicken().eat() // Eating bugs - munch, munch, munch!
Pig().eat()     // Scarfing down corn - NOM NOM NOM!!!
```

*Listing 13.20 - Implementing the* `eat()` *function directly in the* `Pig` *class.*

Alternatively, we can accomplish the same thing by creating *another* class, and using *it* as the delegate of the **`Pig`**. Here's how that looks.

```
class Scarfer(private val food: String) : Eater {
    override fun eat() = println("Scarfing down $food - NOM NOM NOM!!!")
}

class Cow : Eater by Muncher("grass")
class Chicken : Eater by Muncher("bugs")
class Pig : Eater by Scarfer("corn")
```

*Listing 13.21 - Creating a second implementation of* `Eater` *that is used by the* `Pig` *class.*

So, class delegation makes it easy to share *general* code—such as the `eat()` function—across different *specific* types, like `Cow`, `Chicken`, and `Pig` classes.

This is just one way of sharing code across different classes. In the next chapter, we'll explore *abstract* and *open* classes, which can also be used to share code.

# Summary

Thanks to delegation, Roger was able to enjoy his dinner without ever leaving his seat. Even though he only ever interacted with the waiter, each task was fulfilled by the right person. Similarly, in our code, a task can be handed off from one object to another using Kotlin's built-in class delegation feature.

Here's what you learned in this chapter:

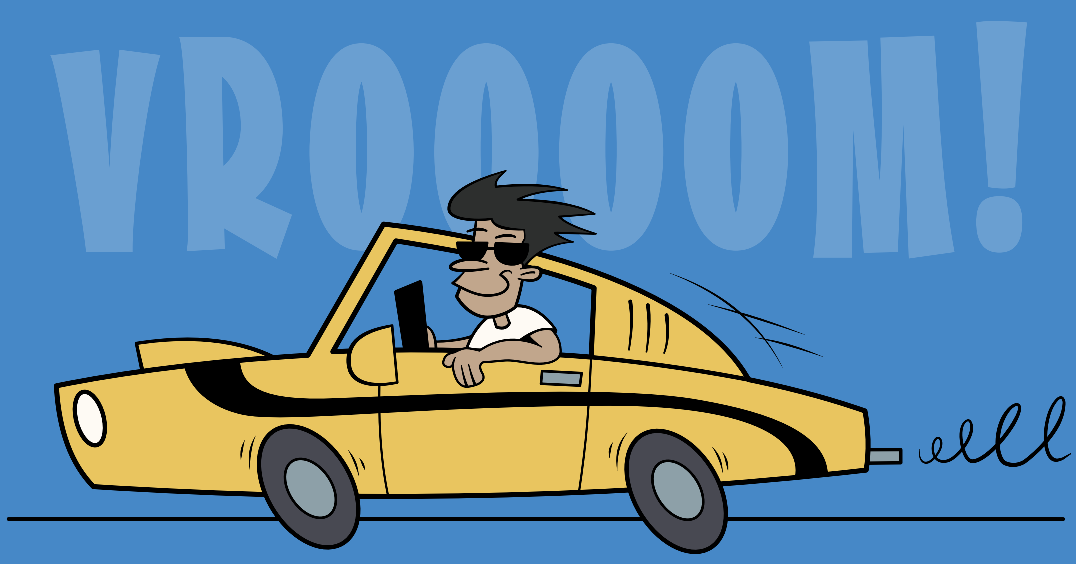
- What delegation is.
- How to manually delegate from one object to another.
- How to use Kotlin's class delegation to automatically delegate.
- How to override particular functions that would otherwise be delegated.
- How to resolve conflicts when two delegates provide an implementation for the same function.
- How to use delegation for general and specific types.

Up next, we'll look at *abstract* and *open* classes—another way to share code among multiple classes!

Kotlin: An Illustrated Guide

Chapter 14

# Abstract and Open Classes



## There's more than one way to avoid duplication!

In Chapter 12, we saw how we could use interfaces to create subtypes, and in the last chapter, we saw how we could use *delegation* with interfaces in order to share general code among specific classes.

In this chapter, we'll learn how we can extend *open and abstract classes* to accomplish these same things with a different approach. Each approach has its advantages and disadvantages, so we'll also look at how they compare to one another.

# Modeling a Car

Each town has its own mix of cars—smooth-running sedans, stubborn old clunkers that might not start, and retro muscle cars that turn heads at every stoplight. In this chapter, we'll ride along with all of them as we explore abstract and open classes!

Let's start by modeling a simple car that can increase its speed with an **`accelerate()`** function.

```
class Car {
    private var speed = 0.0
    private fun makeEngineSound() = println("Vrrrrrr...")

    fun accelerate() {
        speed += 1.0
        makeEngineSound()
    }
}
```

*Listing 14.1 - A simple class to represent a car.*

Each time that we call the **`accelerate()`** function, the car will increase its speed by **`1.0`**[1] and make an engine sound.

```
val myCar = Car()
myCar.accelerate()
```

*Listing 14.2 - Instantiating the **`Car`** class and calling its **`accelerate()`** function.*

```
Vrrrrrr...
```

This works great for many cars because they make a "Vrrrrrr…" sound.

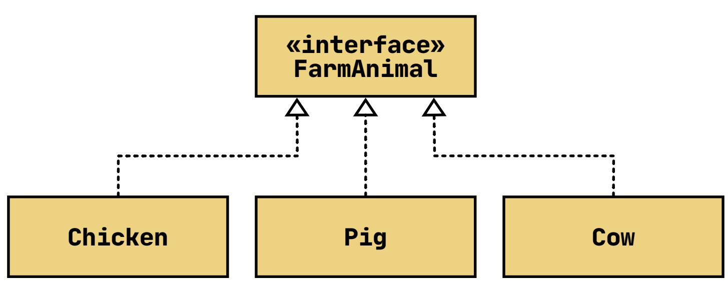

[1] To keep things simple, I'm not including a unit of speed. If it helps, feel free to imagine that the speed is in kilometers per hour, miles per hour, meters per second, or any other unit you like!

But wait… Here comes Old Man Keaton in his rundown, puttering clunker of a car. Instead of a smooth "Vrrrrrr…" sound, it makes a "putt-putt-putt" sound!

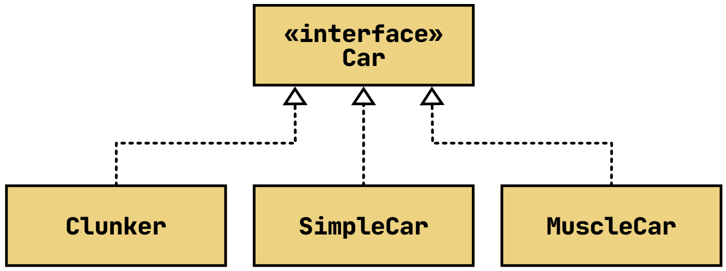

And whizzing by him is Rico in his 1969 muscle car! Go, Rico!


Well, it seems like "Vrrrrrr…" is a fine sound for lots of cars, but we'll need to allow *different* kinds of cars to have *different* engine sounds. How can we accomplish this in Kotlin?

Does this problem sound familiar? In Chapter 12, in order to create multiple animal classes that could each have its own sound, we created an interface named **`FarmAnimal`**, and classes for each specific animal, like **`Chicken`**, **`Pig`**, and **`Cow`**.




If that approach worked for *animals* making sounds, could it also work for *cars*? Could we convert our **`Car`** class into an interface, like **`FarmAnimal`**, and create subtypes for the different kinds of cars?




Well, it's possible to convert the `Car` class into an interface, but it brings with it some rather significant and undesirable changes. Here's how it looks as an interface, compared to the original class. Can you spot the differences?

New Car Interface

```
interface Car {
    var speed: Double
    fun makeEngineSound() =
        println("Vrrrrrr...")

    fun accelerate() {
        speed += 1.0
        makeEngineSound()
    }
}
```

Original Car Class

```
class Car {
    private var speed = 0.0
    private fun makeEngineSound() =
        println("Vrrrrrr...")

    fun accelerate() {
        speed += 1.0
        makeEngineSound()
    }
}
```

Here are the changes we had to make when converting `Car` into an interface:

1. **Visibility** - An interface cannot have `private` members, so we had to make both `speed` and `makeEngineSound()` public. This means that code *outside* of `Car` would be able to set the speed, without going through the `accelerate()` function. Similarly, it'd be possible to call `makeEngineSound()` without accelerating.

2. **State** - Although an interface can declare a property, it can't contain *state*. In other words, it can't itself contain a *value* for that property. So, we had to remove the `= 0.0` from the `speed` property. The implementing classes will have to initialize it instead.

3. **Instantiation** - An interface cannot be instantiated. To work around this, we would have to introduce a class that implements the `Car` interface, and instantiate *that* instead.

Those are concerning, so it'd be great if we could create a subtype *without* introducing those changes. Thankfully, in addition to creating subtypes from an interface, Kotlin also allows us to create subtypes from a *class*. But we can't create a subtype from just *any* old class. By default, a class is **final**, which means that Kotlin will not allow us to create subtypes from it.

Instead, we have to modify the class declaration so that Kotlin knows we want to create subtypes from it. One way to do this is with an **abstract class**.

# Introduction to Abstract Classes

Abstract classes are a lot like interfaces, but they can include private functions, private properties, and state. To create an abstract class, just add the **`abstract`** modifier when declaring it. As you can see below, the only difference between the new abstract class and the original class is the word **`abstract`** at the beginning.

New Abstract Car Class

```kotlin
abstract class Car {
    private var speed = 0.0
    private fun makeEngineSound() =
        println("Vrrrrrr...")

    fun accelerate() {
        speed += 1.0
        makeEngineSound()
    }
}
```

Original Car Class

```kotlin
class Car {
    private var speed = 0.0
    private fun makeEngineSound() =
        println("Vrrrrrr...")

    fun accelerate() {
        speed += 1.0
        makeEngineSound()
    }
}
```

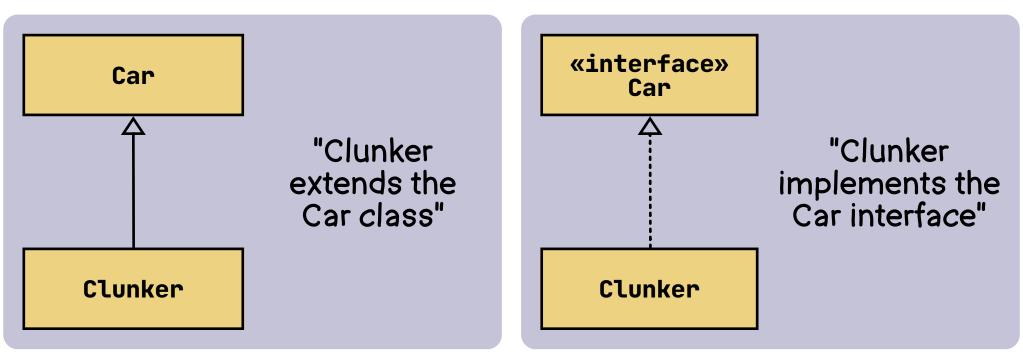
So far, so good! Just like with our original **`Car`** code, the **`speed`** property is private and initialized to **`0.0`**. The **`makeEngineSound()`** function is also private.

There's one problem, though. As with the interface version of **`Car`** above, we can't directly instantiate this abstract class—we can only instantiate its subtypes. Later in this chapter, we'll remedy this, but for now, let's see how we can create a subtype from our new abstract class!

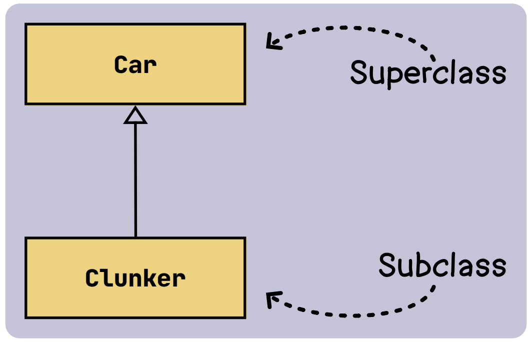
# Extending Abstract Classes

Now that we've got this abstract **`Car`** class, we can create a subtype from it.

- When we create a subtype class from an *abstract class*, we usually say that the subtype class **extends** the abstract class.
- As you might recall from Chapter 12, this differs from when we create a subtype class from an *interface*, in which case we say that the class *implements* the interface.



When extending a class, the class *being* extended is called a **superclass**, and the class that's *extending it* is called a **subclass**.




So, how can we create a subclass from `Car`? Thankfully, the syntax for subtyping a *class* looks a whole lot like the syntax for subtyping an *interface*!

Subtyping a Car Class

```
class Clunker : Car() {
    // ...
}
```

Subtyping a Car Interface

```
class Clunker : Car {
    // ...
}
```

The only difference between these two is the *parentheses*. Why is it that we need parentheses when we subtype a class, but not when we subtype an interface? Because classes have constructors, but interfaces don't. The parentheses here are *invoking the constructor* of the `Car` class.

This is much easier to see if we were to add a constructor parameter, so let's add one for the rate of `acceleration`.

```
abstract class Car(private val acceleration: Double = 1.0) {
    private var speed = 0.0
    private fun makeEngineSound() = println("Vrrrrrr...")

    fun accelerate() {
        speed += acceleration
        makeEngineSound()
    }
}
```

*Listing 14.3 - Adding an `acceleration` property to the `Car` class as a constructor parameter.*

With this change, when we create our `Clunker` subclass, we can pass it a rate of acceleration that's slower than the default of `1.0`.

Now that we're passing a constructor argument, it's easier to see that we're calling the constructor with those parentheses!

```kotlin
class Clunker : Car(0.25)
```

*Listing 14.4 - Instantiating a `Car` class with a literal for the acceleration.*

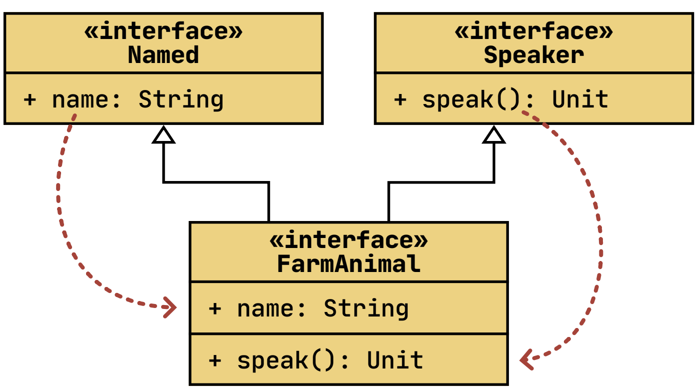
In this case, we hard-coded the acceleration to **`0.25`** for all clunkers. If we don't want *all* clunkers to have the same acceleration, we could also add it as a constructor parameter of the **`Clunker`** class, and just *relay* the argument to the constructor of the **`Car`** class.

```kotlin
class Clunker(acceleration: Double) : Car(acceleration)

val clunker = Clunker(0.25)
```

Relaying constructor arguments from a subclass (e.g., **`Clunker`**) to a superclass (e.g., **`Car`**) is a common practice. Note that **`acceleration`** in **`Clunker`**'s constructor does *not* include the **`val`** or **`var`** keyword—we're just passing it along to the **`Car`** class, which will store it as a property.

# Inheritance

Back in Chapter 12, we learned how one interface can inherit the functions and properties of another interface. In that chapter's example, a **`FarmAnimal`** had a name and it could speak, so it was able to inherit from both a **`Named`** interface and a **`Speaker`** interface.



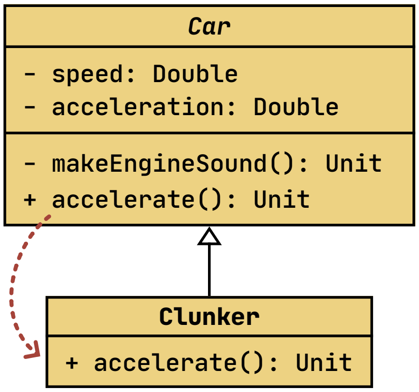

```kotlin
interface Named {
    val name: String
}

interface Speaker {
    fun speak()
}

interface FarmAnimal : Named, Speaker
```

In the code above, the **`FarmAnimal`** interface inherits a few things:

- It gains the **`name`** property from the **`Named`** interface.
- It gains the **`speak()`** function from the **`Speaker`** interface.

So even though the **`FarmAnimal`** interface doesn't explicitly declare those members, it *inherited* them from the other interfaces.

Similarly, when extending an abstract class, the subclass will inherit the functions and properties from the superclass. So, the `Clunker` subclass contains a function named `accelerate()`, even though it's not explicitly declared in its class body, because it inherits that function from `Car`.




```
abstract class Car(private val acceleration...) {
    private var speed = 0.0
    private fun makeEngineSound() = // ...

    fun accelerate() { /*...*/ }
}

class Clunker(acceleration...) : Car(acceleration)
```

For what it's worth, it technically also contains `acceleration`, `speed`, and `makeEngineSound()`, but since those are private, they won't be visible to the subclass. We'll see how to work around this in a moment.

## Interface and Implementation

To understand inheritance, it can be helpful to distinguish between two parts of a class:

1. The visible function and property signatures (that is, their names, parameter types, and return types) of a class make up its **interface**. This term can be confusing, because languages like Kotlin also include a code element called an `interface`, which we covered in Chapter 12. So, when we talk about the "interface of a class", it's not always clear whether we're talking about the public surface area of the class, or an actual `interface` in the class declaration.

2. The code in the *body* of a function or property is called its **implementation**.

To help visualize this, let's look at the code for one of the first classes we wrote, way back in Chapter 4—a Circle.

```
class Circle(
    var radius: Double
) {
    private val pi: Double = 3.14

    fun circumference() = 2 * pi * radius
}
```

*Listing 14.5 - A simple* `Circle` *class that we created in Chapter 4.*

Now, let's take the exact same code, but indent the implementation off to the right, in order to help distinguish between the *interface* and *implementation*.

Interface | Implementation

```
class Circle(
    var radius: Double
) {
                                private val pi: Double = 3.14

    fun circumference()         = 2 * pi * radius
}
```

- We can think of an interface as the way a class looks from the "outside"—its name, its properties and their types, its functions and their parameter and return types, and so on.
- The implementation, on the other hand, is what a class looks like from the "inside"—its functions and properties that are *not* externally visible, the *body* of its functions and properties, and so on. Essentially, its inner workings.

So, when we say that a class is *implementing* an **`interface`** (referring to the code element here), what we really mean is that it's providing an *implementation*—that is, the code in the body—for each function and property that the **`interface`** declares.

Speaker interface

```
interface Speaker {
    fun speak()
}
```

Cow's Interface | Cow's Implementation

```
class Cow : Speaker {
    override fun speak()    = println("Moo!")
}
```

When a class inherits from an **`interface`** or a class, what *exactly* does it inherit? The interface, or the implementation?

- In some cases, it just inherits the *interface*—that is, the function and property signatures. For example, when an **`interface`** does not include a [default implementation](), the class inherits the interface, but must provide its own implementation, such as in the **`Cow`** code above.
- In other cases, it also inherits the *implementation* of those functions and properties. For example, when an interface *does* include a default implementation, the inheriting class can inherit that implementation, such as in the following code.

```
interface Speaker {
    fun speak() = println("...")
}

class Cow : Speaker
```

*Listing 14.6 - Inheriting a default implementation from an interface.*

As we'll see in a moment, these two things hold true when extending an abstract class, as well.

When a subclass inherits an *implementation* from its superclass, it might also have an opportunity to replace or augment the implementation that the superclass provides. This is called **overriding**,[1] and it's how we can customize the sound of a `Clunker`'s engine! Let's look at overriding next.

# Overriding Members

Just like when using delegation, we can override functions and properties from an abstract class in order to specialize the behavior of the subclass—such as to give a `Clunker` a special engine sound! We can't just add the `override` keyword, though, or we'll get a compiler error.

```
class Clunker(acceleration: Double) : Car(acceleration) {
    override fun makeEngineSound() = println("putt-putt-putt")
}
```

*Listing 14.7 - **Error:** makeEngineSound defined in Clunker has no access to makeEngineSound defined in Car, so it cannot override it.*

The problem here is that the `makeEngineSound()` has a `private` visibility modifier in the superclass, as in Listing 14.3 above. When a function or property is `private`, it's *so private* that even its own subclasses can't see it! We can fix that with a different visibility modifier.

## Protected Visibility

A function marked as `private` in the superclass isn't visible in its subclasses. And if you can't see it, you can't override it!

Of course, one option is to remove the `private` modifier, which would make it a public function, but if we do that, then it would be possible to make the engine sound without calling the `accelerate()` function.

```
val car = Clunker(0.25)
car.makeEngineSound()
```

*Listing 14.8 - Bypassing the `accelerate()` function, calling the `makeEngineSound()` function directly.*

We only want the car to make an engine sound when *accelerating*. It'd be great if we could make it so that the `makeEngineSound()` function is visible to *subclasses*, but not to any *other* code.

For these situations, Kotlin provides another visibility modifier, named `protected`. Let's update `makeEngineSound()` so that it's `protected`.

[1] As you might recall, we did the same kind of thing when we used class delegation in the last chapter, and the term "override" is the same as we used then.

```
abstract class Car(private val acceleration: Double = 1.0) {
    private var speed = 0.0
    protected fun makeEngineSound() = println("Vrrrrrr...")

    fun accelerate() {
        speed += acceleration
        makeEngineSound()
    }
}
```

*Listing 14.9 - Adding the* **`protected`** *visibility modifier to the* **`makeEngineSound()`** *function, so that it is visible to subclasses.*

A function or property marked as **`protected`** will be visible to both the current class (e.g., **`Car`**) and its subclasses (e.g., **`Clunker`**), but invisible to code everywhere else. With this, **`makeEngineSound()`** is now visible in the **`Clunker`** subclass. Are we ready to override it now?

```
class Clunker(acceleration: Double) : Car(acceleration) {
    override fun makeEngineSound() = println("putt-putt-putt")
}
```

*Listing 14.10 - **Error:** 'makeEngineSound' in 'Car' is final and cannot be overridden.*

We're still getting a compiler error! Remember how classes are *final* by default? Well, it's the same thing with functions… by default, a function is *final*, which means it can't be overridden in subclasses unless we *explicitly state* that it's allowed. There are two ways to do this.

## Abstract Functions and Properties

The first way is to add the **`abstract`** modifier to the member. When a function is marked with **`abstract`**:

- It *cannot* be implemented in the abstract class.
- It *must* be implemented in the subclass—unless the subclass itself is also abstract!

So, let's remove the function body from **`makeEngineSound()`**, and add the **`abstract`** modifier to it.

```
abstract class Car(private val acceleration: Double = 1.0) {
    private var speed = 0.0
    protected abstract fun makeEngineSound()  // no body allowed here!

    fun accelerate() {
        speed += acceleration
        makeEngineSound()
    }
}
```

*Listing 14.11 - Adding an* **`abstract`** *modifier to the* **`makeEngineSound()`** *function, and removing its implementation.*

With this, we can *finally* override the **`makeEngineSound()`** function.

```
class Clunker(acceleration: Double) : Car(acceleration) {
    override fun makeEngineSound() = println("putt-putt-putt")
}
```

*Listing 14.12 - Overriding the* **`makeEngineSound()`** *function in the* **`Clunker`** *subclass.*

And now we can instantiate and accelerate a clunker.

```
val clunker = Clunker(0.25)
clunker.accelerate()
```

*Listing 14.13 - Instantiating and accelerating a* **`Clunker`**.

And now it makes that *putt-putt-putt* sound that follows Old Man Keaton around everywhere he goes!

```
putt-putt-putt
```

Again, marking a function or property as **`abstract`** means that each non-abstract subclass *must* implement it. But what if we want **`Car`** to have a default implementation for **`makeEngineSound()`**, so that subtypes don't *have* to override it? For this, we have to turn to a different modifier, which we'll explore next.

## Open Functions and Properties

The second way to allow subclasses to override a function or property is to mark it as **`open`**. Open members can have a default implementation in the superclass, so that subclasses don't *have* to provide their own implementation. But they can if they want to. Let's change our **`makeEngineSound()`** function so that it's **`open`** instead of **`abstract`**, and add the body to that function again.

```
abstract class Car(private val acceleration: Double = 1.0) {
    private var speed = 0.0
    protected open fun makeEngineSound() = println("Vrrrrrr...")

    fun accelerate() {
        speed += acceleration
        makeEngineSound()
    }
}
```

*Listing 14.14 - Changing the* **`makeEngineSound()`** *function from* **`abstract`** *to* **`open`**, *which involves adding the body to the function again.*

With this change, we can run the code from Listing 14.13 again, and we'll get the exact same result, because **`Clunker`** still overrides the **`makeEngineSound()`** function.

Let's introduce *another* subclass that does *not* override it.

```
class SimpleCar(acceleration: Double) : Car(acceleration)
```

*Listing 14.15 - A subclass of* **`Car`** *that does not override the* **`makeEngineSound()`** *function.*

When we instantiate it, and call **`accelerate()`** it'll use the default engine sound of "Vrrrrrr…".

```
val car = SimpleCar(1.2)

car.accelerate()
```

*Listing 14.16 - Instantiating and calling* **`accelerate()`** *on a* **`SimpleCar`** *class.*

```
Vrrrrrr...
```

So, to summarize, abstract classes can be extended by other classes. Their functions and properties can be:

- **`abstract`**, in which case they have no body in the abstract class, but subclasses *must* implement them.
- **`open`**, in which case they have a body in the abstract class, but subclasses *may* override them.
- Final (i.e., neither **`abstract`** nor **`open`**), in which case subclasses *cannot* override them.

There's still one problem with our code. As mentioned earlier, like an interface, an abstract class doesn't let us instantiate it directly.

```
val myCar = Car()
```

*Listing 14.17 - **Error:** Cannot create an instance of an abstract class.*

Instead, we have to instantiate one of its subclasses. To fix this, instead of making **`Car`** an *abstract* class, we can consider making it an open class.

# Introduction to Open Classes

An open class is a class that can be both extended *and* instantiated directly. We can change our **`Car`** class from an abstract class to an open class by simply replacing the keyword **`abstract`** with the keyword **`open`**.

```
open class Car(private val acceleration: Double = 1.0) {
    // ...
}
```

*Listing 14.18 - Using the* **`open`** *modifier on the* **`Car`** *class.*

With this simple change, we can now instantiate a **`Car`** directly.

```
val myCar = Car()
```

*Listing 14.19 - Directly instantiating a* **`Car`**.

There's a catch, though—while an open class can have functions and properties that are either **`open`** or final, it cannot contain any that are **`abstract`**. That makes sense, though—imagine if this open **`Car`** class had an abstract function named **`honk()`**, which naturally could have no body. Now, if we were to instantiate and call **`honk()`** on the car, what could we possibly expect to happen?

So again, open classes cannot contain **`abstract`** members. Next, let's look at how we can use a visibility modifier to give subclasses special access to the functions and properties of a superclass.

# Getter and Setter Visibility Modifiers

Let's create another subclass of **`Car`**. This one's a muscle car, and the sound of its engine depends on how fast it's going. Unfortunately, when we try to reference the **`speed`** variable, we get a compiler error.

```
class MuscleCar : Car(5.0) {
    override fun makeEngineSound() = when {
        speed < 10.0 -> println("Vrooooom")
        speed < 20.0 -> println("Vrooooooooom")
        else         -> println("Vrooooooooooooooooooom!")
    }
}
```

*Listing 14.20 - **Error:** Cannot access 'speed': it is invisible (private in a supertype) in MuscleCar.*

The problem is that, in the **`Car`** class, the **`speed`** property has a **`private`** visibility modifier on it.

```
open class Car(private val acceleration: Double = 1.0) {
    private var speed = 0.0
    // ...
}
```

*Listing 14.21 - The* **`private`** *visibility modifier here prevents subclasses from seeing the* **`speed`** *property.*

As we saw earlier, we can use the **`protected`** modifier so that subclasses can see the **`speed`** property.

```
open class Car(private val acceleration: Double = 1.0) {
    protected var speed = 0.0
    // ...
}
```

*Listing 14.22 - Changing the visibility of the* **`speed`** *property from* **`private`** *to* **`protected`**.

With this change, our **`MuscleCar`** code from Listing 14.20 now compiles just fine!

Let's not celebrate just yet though. With this change, subclasses can now *bypass* the **`accelerate()`** function, and directly set the speed to anything they want!

```
class Clunker(acceleration: Double) : Car(acceleration) {
    override fun makeEngineSound() {
        println("putt-putt-putt")
        speed = 999.0 // Yikes! Shouldn't be able to increase the
                      // speed without calling accelerate()!
    }
}
```

*Listing 14.23 - Bypassing the **`accelerate()`** function by setting the value of **`speed`** directly.*

Ideally, we want to let the subclasses *get* the **`speed`** value, but prevent them from *setting* it.

Thankfully, in Kotlin, a property's *getter* can have a different visibility modifier from its *setter*. The syntax can seem a little unnatural at first, but here's how it looks.

```
open class Car(private val acceleration: Double = 1.0) {
    protected var speed = 0.0
        private set
    // ...
}
```

*Listing 14.24 - Making the visibility of the **`speed`** property **`protected`** on its getter and **`private`** on its setter.*

This code indicates that:

- The **`speed`** property is **`protected`**, so subclasses of **`Car`** can *get* its value.
- The **`speed`** property's *setter* visibility is **`private`**, which means only the **`Car`** class itself can *set* the value.

By the way, if you'd prefer to keep everything on one line, you can just use a semicolon to separate them, like this.

```
open class Car(private val acceleration: Double = 1.0) {
    protected var speed = 0.0; private set
    // ...
}
```

*Listing 14.25 - Setting different visibility for a property's getter and setter on a single line.*

For what it's worth, this is one of two occasions when I might use a semicolon in Kotlin. The other is when adding functions to an enum class, as we saw in Chapter 5.

# Combining Interfaces and Abstract/Open Classes

As we saw in Chapter 12, a class can implement multiple interfaces. It's also possible to implement interfaces *and* extend a class. To do this, just separate the names of the interfaces and/or superclass with a comma.

```
class NamedCar(override val name: String) : Car(3.0), Named
```

*Listing 14.26 - Declaring that* **`NamedCar`** *both extends a class and implements an interface.*

The biggest critical difference between interfaces and abstract/open classes is that a subclass can only extend one class. Implement as many interfaces as you want, but you're stuck with no more than one superclass.[1] This is why interfaces can be much more flexible than abstract and open classes.

# Comparing Interfaces, Abstract Classes, and Open Classes

Between interfaces, abstract classes, and open classes, there are a lot of options for creating subtypes, and it can be hard to know which option is the most appropriate for different circumstances. Software design decisions like this are the subject of many books—and many debates!

Although software analysis and design aren't in scope for this book, it's still worth summarizing the significant characteristics of each option, so here's a handy-dandy chart to help get you pointed in the right direction!

| Characteristic | Interface | Abstract Class | Open Class |
|---|---|---|---|
| Can inherit from it? | Yes | Yes | Yes |
| Can inherit from multiple? | Yes | No | No |
| Can be instantiated directly? | No | No | Yes |
| Can include non-implemented members? | Yes | Yes | No |
| Can include default implementation? | Yes | Yes | Yes |

# Subclasses and Substitution

As mentioned in Chapter 12, we can use a subtype anywhere that the Kotlin code expects a supertype. This is true not only for interfaces, but also for abstract and open classes. So, we can explicitly specify the type of a variable as a *superclass* (e.g., **`Car`**), while actually assigning an instance of a *subclass* (e.g., **`MuscleCar`**).

[1] Like many other programming languages, Kotlin does not allow multiple class inheritance because of the ambiguity created when two superclasses have different implementations of the same function. For more information about this, see *The Diamond Problem* in Wikipedia's article on Multiple Inheritance.

```
val car: Car = MuscleCar()
```

*Listing 14.27 - Assigning a* **`MuscleCar`** *to a variable that has a type of* **`Car`**.

The same holds true for calling a function.

```
fun drive(car: Car) {
    // ...
}

drive(MuscleCar())
```

*Listing 14.28 - Sending a* **`MuscleCar`** *object to a function that has a* **`Car`** *parameter.*

If a function has a parameter of type **`Car`**, it will happily receive a **`MuscleCar`**, because—by definition—the subclass has at least all the same functions and properties as its superclass. It could have *more* than its superclass, but it will never have fewer.

This ability to use a subtype where a supertype is expected, along with the ability of the subtypes to override functions and properties, is called **polymorphism**[1]. It's a big word that, apart from software development, probably doesn't mean anything to you (unless you happen to be a biologist), but it's still important to know, because it's considered one of the pillars of object-oriented programming.

# Class Hierarchies

So far, every subclass we've created has been a final class, but it's entirely possible for a subclass itself to *also* be an abstract or open class. For example, a clunker that doesn't drive at all might be classified as a "junker". To accommodate this, we could make **`Clunker`** an open class, and extend it with a new class named **`Junker`**.

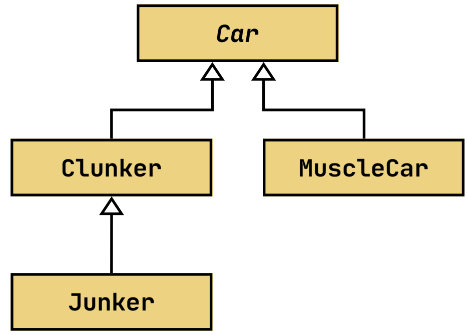
```
open class Clunker(acceleration: Double) : Car(acceleration) {
    override fun makeEngineSound() = println("putt-putt-putt")
}

class Junker : Clunker(0.0)
```

*Listing 14.29 - Updating* **`Clunker`** *so that it is both a subclass and a superclass.*

Now, **`Clunker`** is *both* a subclass of **`Car`** *and* a superclass of **`Junker`**.

Once we've got more than a few classes, it can be helpful to visualize the relationships of the different classes with a UML class diagram, as shown below.

[1] More precisely, this is called *subtype polymorphism*. There's another kind called "parametric polymorphism", which we typically just refer to as "generics". We'll learn about generics in Chapter 18.

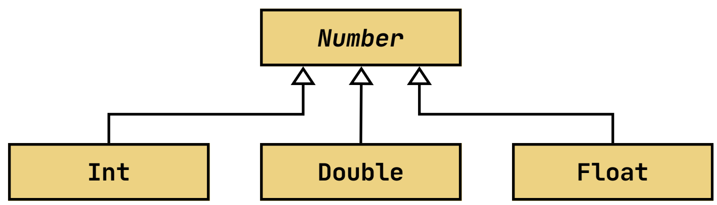



This visualization makes it easy to see how these classes are related in a **class hierarchy**, where the general classes are toward the top, and as you go down the diagram, the classes become more specific.

The **depth** of a class hierarchy is determined by how many layers of classes there are in the hierarchy. In the diagram to the right, we see three layers of depth.

Generally, it's a good idea to limit the depth of a class hierarchy to only a few layers. Otherwise, it gets hard to keep track of which superclasses are providing the different functions and properties, which subclasses are depending on them, and in what *ways* they're depending on them.

# The Any Type



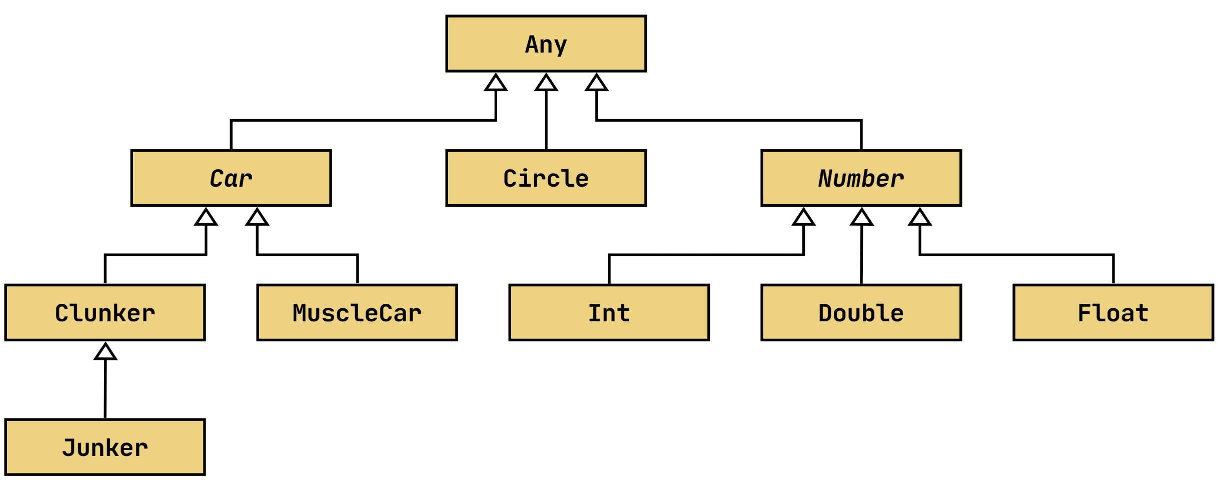

Supertypes and subtypes are not limited to our own classes and interfaces. Many of the classes in Kotlin's standard library implement interfaces and extend abstract or open classes. For example, the basic number types like `Int`, `Double`, and `Float` are all subclasses of an abstract class named `Number`.

In fact, *every* Kotlin class that we write will have at least *one* superclass. For example, way back in Listing 4.1, we created the simplest class possible. Here it is again.

```
class Circle
```

*Listing 14.30 - The simplest class, from Chapter 4.*

Even though this class doesn't *explicitly* extend a class, it still *implicitly* extends an open class named `Any`. This class is at the very top of the class hierarchy in Kotlin, so even classes that are otherwise unrelated have the `Any` class in common with each other.



The `Any` class provides a few essential functions that are inherited by all other classes—`equals()`, `hashCode()`, and `toString()`. These three functions can be overridden, but we don't often need to do that, because Kotlin has a special kind of class that will override those functions for us, giving them implementations that we usually need.

We'll learn all about that in the next chapter, as we explore *data classes*!

# Summary

Congratulations! After finishing this chapter, you're all fueled up and ready to use abstract and open classes in your projects.

In this chapter, you learned:

- What abstract classes are.
- What it means to extend a class.
- How functions and properties are inherited from superclasses.
- The difference between the concepts of interface and implementation.
- How to override functions and properties from a superclass.
- How protected visibility gives subclasses access to the members of a superclass.
- The difference between abstract members and open members.
- How open classes can be instantiated and include default implementations.
- How getters and setters can have different visibility modifiers.
- How one class can both extend a class and implement interfaces.
- How classes form a class hierarchy.
- How the `Any` type is at the top of the class hierarchy in Kotlin.

Next, we'll shift gears to explore *data classes*—a special kind of class that can supercharge our objects!

# Data Classes and Destructuring

# Lots of power with just one modifier!

At the end of the last chapter, we saw how all objects in Kotlin inherit three functions from an open class called **`Any`**. Those functions are **`equals()`**, **`hashCode()`**, and **`toString()`**.

In this chapter, we're going to learn about *data classes*, which are super-powered classes that are especially helpful when we've got an immutable class that mainly just holds properties.

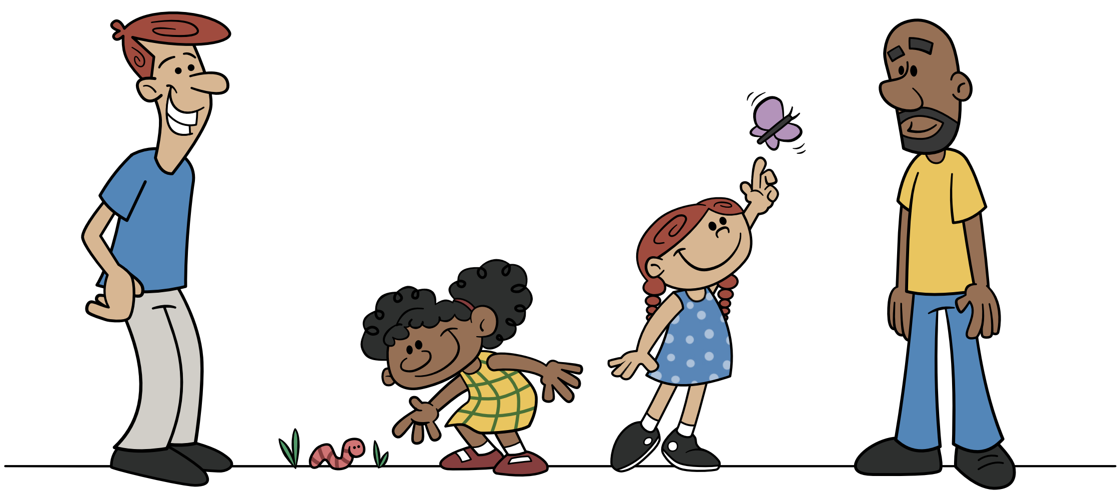
To better understand data classes, let's first explore each of the three functions above, and see what's involved when we override them!

# Overriding `equals()`

## Reference Equality

Two fathers were crossing paths at the local park, with their daughters in tow, when each accidentally let go of his daughter's hand.

Both of these girls were named Fiona. However, despite having the *same* name, they were two *different* girls, so when the fathers turned around, it was important that each collected his *own* daughter, not just the first girl he saw who was named Fiona!

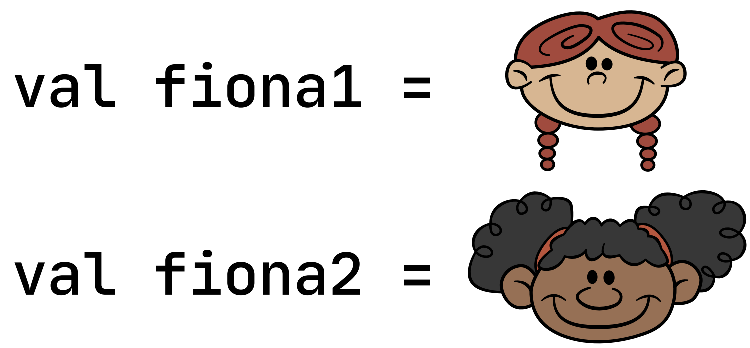


Similarly, in Kotlin, there are times when we want to check to see if an object is the exact instance that we want. To do this, we can use the *equality operator*, which is two adjacent equal signs. Let's demonstrate this by creating a class to represent the two girls, and instantiate an object for each.

```
class Child(val name: String)

val fiona1 = Child("Fiona")
val fiona2 = Child("Fiona")

println(fiona1 == fiona2) // false
```

*Listing 15.1 - Two variables are not considered equal, even though their objects have the same property values.*

When using the equality operator on these two objects, we see that they are *not* equal. In other words, they're two *different* `Child` objects.



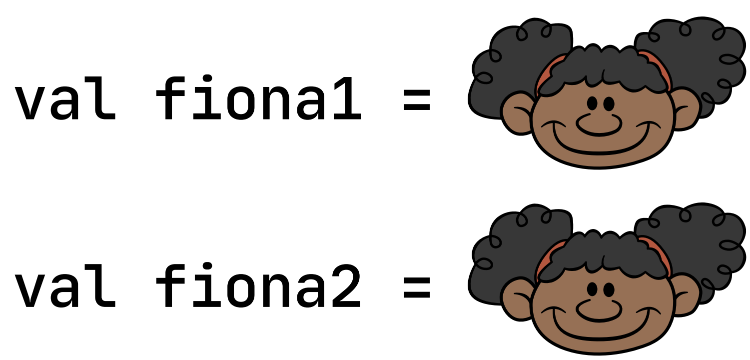

That's exactly what we want! After all, these two girls are different children, even though they both have the same name.

Of course, if we assign the one `Child` object to two different variables, then the equality operator will indicate that those two variables are equal, because they both refer to the same exact object instance.

```
val fiona1 = Child("Fiona")
val fiona2 = fiona1

println(fiona1 == fiona2) // true
```

*Listing 15.2 - Two variables are considered equal when they refer to the same object.*

In the code above, `fiona1` and `fiona2` are both assigned the same object, so they're equal.



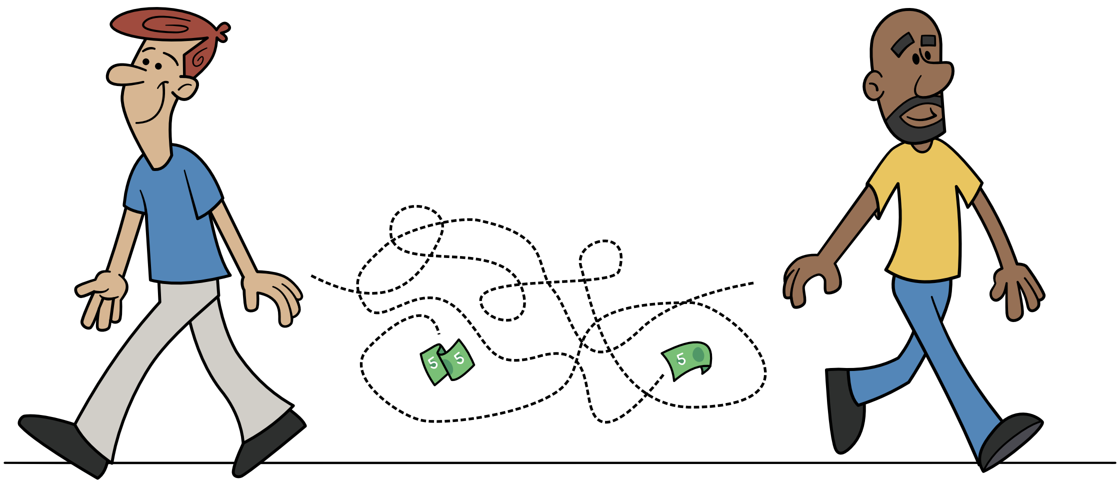

This kind of equality is sometimes called **reference equality**,[1] because as long as the two variables *refer* to the same object instance, then they will be considered equal.

By default, Kotlin uses reference equality when we use the equality operator to compare two objects.

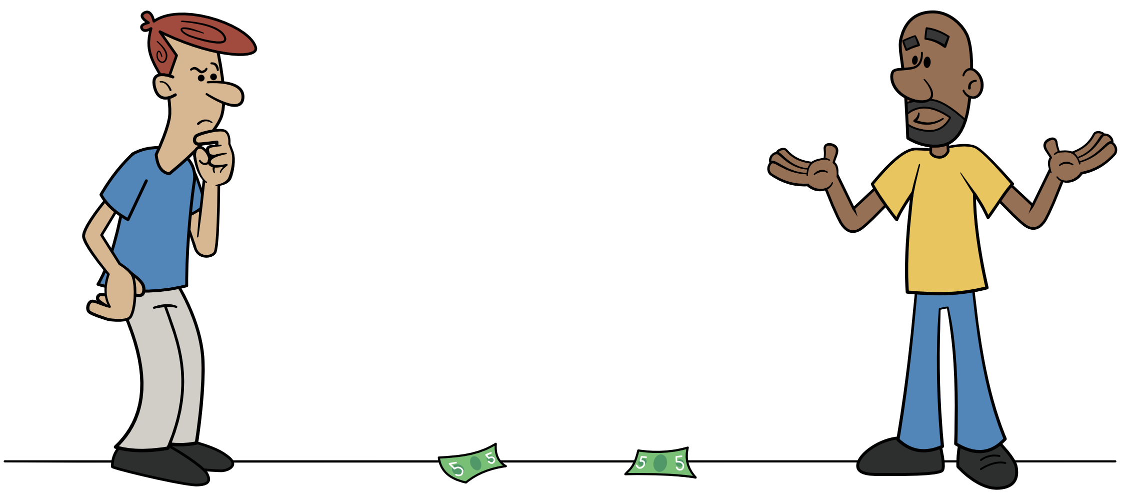
## Value Equality

The next day, the two fathers were again crossing paths in the park. This time, they each accidentally let go of a *five-dollar bill* at the same time.

[1] This is sometimes also called *identity equality*, or more formally, *referential equality*.

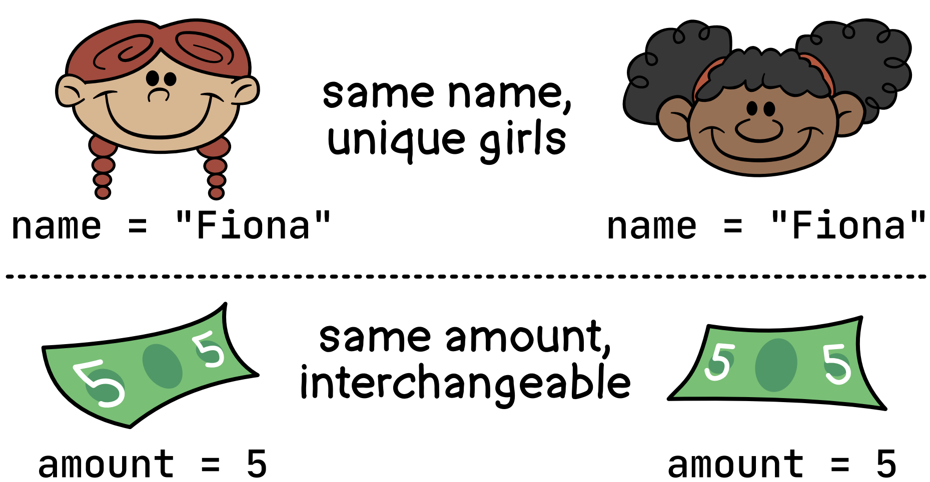


When they turned around, they looked at the dollar bills on the ground, but they weren't sure which bill belonged to which person.



However, each bill is worth the same amount—five dollars. Unlike the previous day when it was important for each father to pick up his own exact daughter, in *this* case, it doesn't matter whether each person picks up the *exact* bill that he dropped. As long as each of them picks up one of the five-dollar bills, it's fine, because the two bills are *equal* to one another.

In other words, some things are interchangeable as long as they have certain *characteristics* that are the same.



Similarly, in Kotlin, when objects are considered equal based on their property *values* rather than their identity, it's often called **value equality**.[1]

Since we would consider two five-dollar bills to be equal to each other, we would probably want a **`DollarBill`** class to have *value equality* rather than *reference equality*.

The code below is roughly the same as Listing 15.1 above, but with a **`DollarBill`** class instead of a **`Child`** class.

```
class DollarBill(val amount: Int)

val bill1 = DollarBill(5)
val bill2 = DollarBill(5)

// We want this to be true!
println(bill1 == bill2) // false
```

*Listing 15.3 - How can we make it so that two objects are equal based on their property values?*

As you can see, when we run this, we get **`false`**. How can we get this code to print **`true`**?

Under the hood, when we use the equality operator, it calls into the **`equals()`** function to determine whether the two objects are considered equal. The implementation of **`equals()`** that is handed down from the **`Any`** class will check to see if the two variables *refer to the same object*, which is why reference equality is the default in Kotlin. So if we want the equality operator to act differently for a particular class, we'll need to override the **`equals()`** function of that class.

In the case of this **`DollarBill`** class, one simple way to achieve this is to manually delegate the **`equals()`** call to the **`amount`** property. Let's try overriding this function in the **`DollarBill`** class. Note that in the **`Any`** class, this function has a parameter of type **`Any?`**, and a return type of **`Boolean`**, so we'll use the same types in our **`equals()`** function here.[2]

```
class DollarBill(val amount: Int) {
    override fun equals(other: Any?) =
        amount.equals(other.amount)
}
```

*Listing 15.4 - **Error:** Unresolved reference: amount.*

Well, that didn't work. The problem is that the **`other`** parameter has a type of **`Any?`**, so that any two objects in Kotlin can be compared to each other, even if their types don't match. Since **`other`** might not actually be a **`DollarBill`** object, it won't necessarily have a property named **`amount`**.

[1] You might also hear this referred to as *content equality* or *structural equality*.

[2] When overriding a function, we often use the same parameter types and return types that are specified by the same function in the superclass. However, Kotlin also allows you to specify a more general parameter type or a more specific return type. This feature is called *variance*. We'll learn more about this in Chapter 19 when we look at how variance works for generics.

To fix this, we'll need to first check whether the type of **`other`** is **`DollarBill`**.

- If it is, then we can just use a smart cast to compare the **`amount`** values.
- If it isn't, then we can just return **`false`**.

```
class DollarBill(val amount: Int) {
    override fun equals(other: Any?) =
        if (other is DollarBill) amount.equals(other.amount) else false
}
```

*Listing 15.5 - Properly overriding the **`equals()`** function to achieve value equality.*

With this change, two **`DollarBill`** objects will be equal to one another as long as:

1. They're both instances of **`DollarBill`**.
2. They both have the same value for the **`amount`** property.

When we run the code again, we'll see that **`bill1`** and **`bill2`** are now considered equal!

```
val bill1 = DollarBill(5)
val bill2 = DollarBill(5)

println(bill1 == bill2) // true
```

*Listing 15.6 - These two **`DollarBill`** objects are considered equal because we overrode the **`equals()`** function.*

## By the Way: Referential Equality Operator

Even when we override the **`equals()`** function to give a class *value equality*, we can still check to see whether two variables refer to the same instance.

To do this, we can use the **referential equality operator** instead of the regular equality operator.

The referential equality operator is *three* contiguous equal signs instead of two. Continuing with the code from Listing 15.5 and Listing 15.6 above, we can compare **`bill1`** and **`bill2`** using both the *equality operator* and the *referential equality operator*.

```
println(bill1 == bill2)  // true  - i.e., according to `equals()` function
println(bill1 === bill2) // false - i.e., not the same object instance
```

So, by overriding the **`equals()`** function, we were able to give our **`DollarBill`** class value equality instead of reference equality! However, there's a problem that shows up when we try to use this class with certain collection types. This brings us to the **`hashCode()`** function.

# Overriding `hashCode()`

Little Fiona is starting a collection of contemporary US dollar bills. In order to complete her collection, she's going to need one bill of each of the seven denominations: $1, $2, $5, $10, $20, $50, and $100.

As you recall from Chapter 8, multiple objects can be stored in a collection type called a `Set`, which guarantees that each of its elements is unique. In other words, if we try to add an object to a set that it already contains, nothing will change.


We can use a `Set` to keep track of Fiona's dollar bills.

```
val denominations = mutableSetOf<DollarBill>()
```

*Listing 15.7 - Creating a mutable set to hold unique `DollarBill` instances.*

Fiona has collected bills of three different denominations so far: $1, $2, and $5. We can add those to her collection and print out the size, just to make sure it's got three unique items in it.

```
val denominations = mutableSetOf<DollarBill>()

denominations.add(DollarBill(1))
denominations.add(DollarBill(2))
denominations.add(DollarBill(5))

println(denominations.size) // 3
```

*Listing 15.8 - Adding three unique `DollarBill` objects to a mutable set.*

Perfect!

One day, Fiona finds a one-dollar bill, but can't remember if she already collected that one. What happens when we try to add that second one-dollar bill to the set?

```
val denominations = mutableSetOf<DollarBill>()

denominations.add(DollarBill(1))
denominations.add(DollarBill(2))
denominations.add(DollarBill(5))
denominations.add(DollarBill(1)) // duplicate entry!

println(denominations.size) // 4
```

*Listing 15.9 - The set includes a `DollarBill` with the same amount as another in the set.*

Yikes! Instead of rejecting the duplicate, the **denominations** set happily included it as a fourth element! Why did this happen? After all, we overrode the **equals()** function in the **DollarBill** class back in Listing 15.5!

**Set** itself is just an interface, and when we call **mutableSetOf()** it returns a specific implementation of **Set**, called **LinkedHashSet**.

A **LinkedHashSet** does not *primarily* use the **equals()** function to determine whether it already contains an object. Instead, it starts with the **hashCode()** function, and only calls **equals()** when an object with the same hash code already exists in that set.[1]

Because of this, it's a best practice to override **hashCode()** any time we override **equals()**. In our case, since we're already delegating to the **amount** property for **equals()**, we can just do the same for **hashCode()**.

```
class DollarBill(val amount: Int) {
    override fun equals(other: Any?) =
        if (other is DollarBill) amount.equals(other.amount) else false

    override fun hashCode() = amount.hashCode()
}
```

*Listing 15.10 - Overriding the* **hashCode()** *function.*

Easy! With this change, when we run Listing 15.9 again, the set will correctly disregard the duplicate one-dollar bill, resulting in a size of 3 instead of 4.

```
val denominations = mutableSetOf<DollarBill>()

denominations.add(DollarBill(1))
denominations.add(DollarBill(2))
denominations.add(DollarBill(5))
denominations.add(DollarBill(1)) // duplicate entry!

println(denominations.size) // 3 - Success!
```

*Listing 15.11 - The set now omits the duplicate entry, because we overrode the* **hashCode()** *function.*

Well, our **DollarBill** class is *almost* doing everything we want. Before we see how data classes can make our lives easier, let's override that third and final function from the **Any** class, **toString()**.

# Overriding toString()

Although we've used the **println()** function frequently, we haven't examined it closely yet. As you know, we can pass an argument to this function, and it prints it out to the screen. We've often passed it a string, like this.

[1] Note that this same problem also applies to maps, because **mutableMapOf()** returns a hash-based implementation called **LinkedHashMap**.

```
println("Hello, Kotlin!")
```

*Listing 15.12 - Passing a string to the* **`println()`** *function.*

However, we aren't limited to passing strings. We can pass literally *any* object to this function. For example, we can send it an instance of our **`DollarBill`** class.

```
println(DollarBill(100))
```

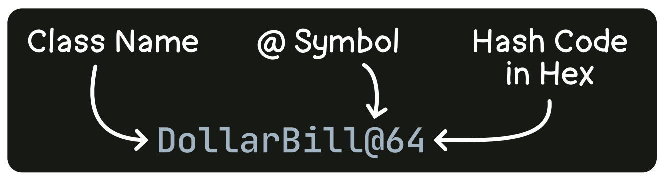
*Listing 15.13 - Passing an object to the* **`println()`** *function.*

When we run this, we'll see this printed out.

```
DollarBill@64
```

When we pass an object to the **`println()`** function, it will call into the **`toString()`** function on that object. By default, this function returns a string that looks like the one above. This string has three parts to it

1. The name of the class.
2. An **`@`** sign.
3. The hash code of the object, in hexadecimal.[1]




As you recall, the **`DollarBill`** class is delegating the **`hashCode()`** call to the **`amount`** integer in Listing 15.10. For an integer, the hash code is simply the value of the integer itself. So, if we assign the value 100 to an integer variable, its hash code is also 100. However, since **`toString()`** converts that hash code to hexadecimal, it *appears* as 64.

The **`toString()`** function in this class would be much more helpful if it were to show the name of the class and the value of the **`amount`** property in *decimal* rather than *hexadecimal*. While we're at it, it'd be helpful to include a label indicating what that number represents (i.e., "amount"). Let's override the **`toString()`** function and return a string that includes those things.

```
class DollarBill(val amount: Int) {
    override fun equals(other: Any?) =
        if (other is DollarBill) amount.equals(other.amount) else false

    override fun hashCode() = amount.hashCode()

    override fun toString() = "DollarBill(amount=$amount)"
}
```

*Listing 15.14 - Overriding the* **`toString()`** *function.*

[1] Most of us have grown up using numbers where each digit has one of ten possible values - 0 through 9. Since there are ten possible values, this is sometimes called the Base-10 or decimal numeral system. Hexadecimal is a numbering system where each digit can have up to 16 values, so it's also called Base-16. After 0-9 come A, B, C, D, E, and F. For example, the number "C" in hexadecimal represents the number 12 in decimal, and the number 10 in hexadecimal represents decimal 16.

After making this change, when we call **`println()`** with a **`DollarBill`** object, we'll get more helpful output.

```
println(DollarBill(100))
```

*Listing 15.15 - Calling **`println()`** with a **`DollarBill`** object.*

```
DollarBill(amount=100)
```

Fantastic!

Well, we've made a lot of changes to our **`DollarBill`** class now. Let's review everything that we did.

1. We made it so that two instances of **`DollarBill`** are equal to each other, as long as they have the same **`amount`** values. In other words, we gave it *value equality* instead of *reference equality*.
2. We made it so that they are also treated as equal in sets and maps.
3. We created a more helpful implementation of **`toString()`**.

We achieved all of these things by overriding the three functions from the **`Any`** class—**`equals()`**, **`hashCode()`**, and **`toString()`**. Now that we understand why we might want to override these functions, it's finally time to see how data classes can make our lives much easier!

# Introduction to Data Classes

After all the changes we made, here's the code that we ended up with.

```
class DollarBill(val amount: Int) {
    override fun equals(other: Any?) =
        if (other is DollarBill) amount.equals(other.amount) else false

    override fun hashCode() = amount.hashCode()
    override fun toString() = "DollarBill(amount=$amount)"
}
```

*Listing 15.16 - The full code for the **`DollarBill`** class, with all three overrides.*

The **`DollarBill`** example has been rather simple. After all, it only has a *single* property. What would happen if we tried to achieve the same things for a class that includes multiple properties? Implementing **`toString()`** would be straightforward. However, **`equals()`** would be a bit more difficult, and **`hashCode()`** would be even *more* involved!

The good news is that whether our class has a single property or a dozen, Kotlin can *automatically* accomplish everything that we've already done in this chapter—overriding **`equals()`**, **`hashCode()`**, and **`toString()`**—and all we have to do is declare our class to be a **data class**. To do this, we just add the keyword **`data`** before the class declaration, like this.

```
data class DollarBill(val amount: Int)
```

*Listing 15.17 - Declaring a data class.*

In this code, we haven't provided an override for **`equals()`**, **`hashCode()`**, or **`toString()`**. In fact, this **`DollarBill`** doesn't even have a *class body* at all! And yet, in just one line, this class does *everything* that Listing 15.16 does!

```
val bill1 = DollarBill(100)
val bill2 = DollarBill(100)

bill1 == bill2                  // true
mutableSetOf(bill1, bill2).size // 1
println(bill1)                  // DollarBill(amount=100)
```

*Listing 15.18 - Demonstrating that a data class accomplishes everything that our three overrides did.*

Again, the **`DollarBill`** class only includes a *single* property, but data classes can easily provide structural equality and a nice **`toString()`** result for classes that have *multiple* properties. For example, here's an **`Address`** class with three properties.

```
data class Address(
    val street: String,
    val city: String,
    val postalCode: String
)
```

*Listing 15.19 - A data class with three properties.*

As this next code listing demonstrates, instances of **`Address`** use value equality, and they print out nicely.

```
val address1 = Address("123 Maple Ave", "Berrytown", "56789")
val address2 = Address("123 Maple Ave", "Berrytown", "56789")

address1 == address2                  // true
mutableSetOf(address1, address2).size // 1
println(address1)
// Address(street=123 Maple Ave, city=Berrytown, postalCode=56789)
```

*Listing 15.20 - Using a data class that has three properties.*

So, data classes give us a lot of power, automatically generating useful implementations of **`equals()`**, **`hashCode()`**, and **`toString()`**. The superpowers don't stop there, though! Data classes also include a function named **`copy()`**, which we'll look at next.

# Copying Data Classes

The properties of a data class can be declared with either **val** or **var**, but Kotlin developers tend to use data classes primarily for *immutable* data. In other words, it's common to use only **val** properties in a data class.

As you know, when a class has a mutable property, we can simply assign it a new value. For example, here we have a data class that represents a book. Its **title** property is read-only, but its **price** property is mutable.

```
data class Book(val title: String, var price: Int)
```

*Listing 15.21 - A simple data class to represent a book.*

When the price of the book increases, we can just update its **price** property.

```
val book = Book("The Malt Shop Caper", 18)

// The price just went up!
book.price = 20
```

*Listing 15.22 - Changing the price of a book object.*

It's easy enough to change the value of the **price** property when it's declared with **var**. But what about properties that are declared with **val**?

Naturally, we can't change the value of a **val** property, but instead, we can create a *copy* of the entire object, substituting the new value in that copy. This approach is similar to the one we used in Chapter 8 when we created new lists by adding an element to an existing list with the plus operator.

Let's update the **Book** class so that the **price** property is declared with **val**.

```
data class Book(val title: String, val price: Int)
```

*Listing 15.23 - Changing the **price** property so that it's read-only.*

With this change, when the price goes up, we can create a new variable called **newBook**, which has the *same* **title** as the original, but with the *new* **price**.

```
val book = Book("The Malt Shop Caper", 18)

// The price just went up!
val newBook = Book(book.title, 20)
```

*Listing 15.24 - Instantiating a second **Book** variable with the title from the first.*

Now, this is easy enough to do with just *two* properties, but the more properties we add, the more tedious it becomes to make a copy. To demonstrate this, let's add four more properties to the **Book** class.

```kotlin
data class Book(
    val title: String,
    val price: Int,
    val author: String,
    val width: Int,
    val height: Int,
    val isbn: String,
)

val book = Book("The Malt Shop Caper", 18, "Slim Chancery", 6, 9, "020516918K")

// The price just went up!
val newBook = Book(book.title, 20, book.author, book.height, book.width, book.isbn)
```

*Listing 15.25 - Manually copying an object that has lots of properties.*

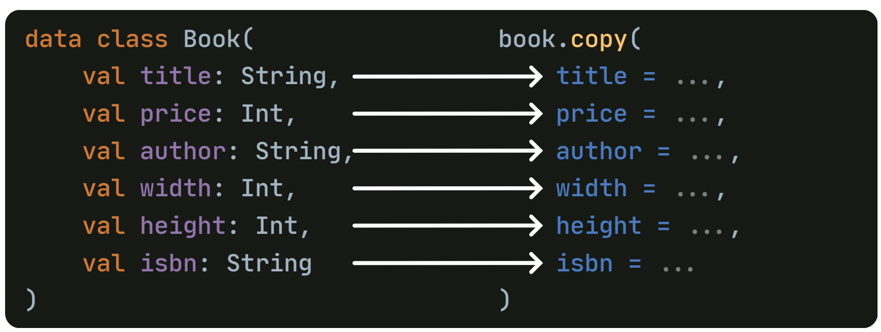
This is a lot of boilerplate, and it's easy to accidentally get something mixed up when relaying the values from the old object to the new one. In the code above, did you notice that the **`height`** and **`width`** got swapped?

To avoid all that boilerplate and reduce the likelihood of these kinds of errors, data classes have a powerful function called **`copy()`**. For the book example above, instead of manually relaying each property to the **`Book`** constructor, we can just call **`copy()`** on the original book, and give it a new value for **`price`**, like this.

```kotlin
val newBook = book.copy(price = 20)
```

*Listing 15.26 - Using the **`copy()`** function that is included in data classes.*

The **`copy()`** function has a *parameter* for each *property* in the data class. Since our **`Book`** data class has 6 properties, its **`copy()`** function has a total of 6 parameters, each of which defaults to the current value of the property.

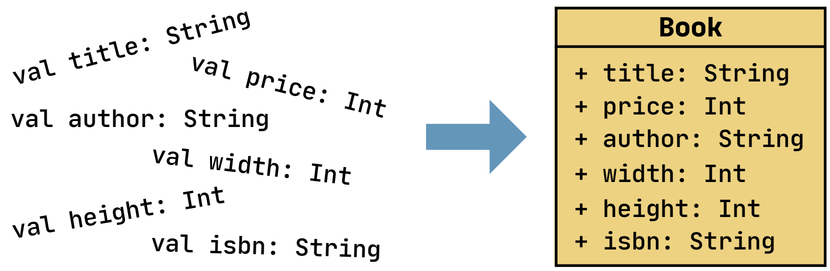



When calling the **`copy()`** function, simply include named arguments for any properties that you want to change, and omit arguments for any properties that you want to stay the same. In Listing 15.26, we only provided the **`price`** parameter, so **`newBook`** will have a price of **`20`**, but all other properties will have the same values that they had in the original **`book`** object.

As you can see, the **`copy()`** function is an incredibly powerful way to work with immutable classes, allowing our code to effectively change data, without actually mutating the individual properties! There's one more feature that data classes provide, which is the ability to *destructure* its properties. Let's dive in!

# Destructuring

When we've got a lot of values that all pertain to some concept, it usually makes sense to put them together.




For example, if we've got a title, price, author, width, height, and an ISBN, we usually don't want to deal with them as *individual* variables.

Instead, we want them grouped all together in one structure, such as a **`Book`** class.

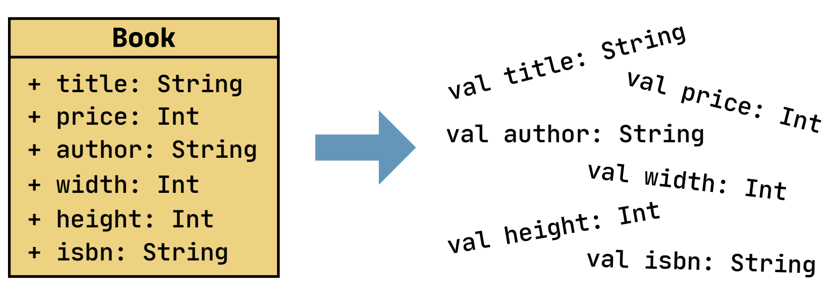
Here's the **`Book`** data class that we used earlier, which groups together all of the variables mentioned above.

```kotlin
data class Book(
    val title: String,
    val price: Int,
    val author: String,
    val width: Int,
    val height: Int,
    val isbn: String,
)
```

*Listing 15.27 - The* ***Book*** *class from Listing 15.25.*

When we assemble values into a single class like this, it's clear that these different values are all associated with one another and that, taken together, they represent the concept of a *book*. This usually makes it easier for developers to understand—for example, it's clear that the **`title`** represents the title of a book, not the title of a movie. This also makes it convenient to pass all of these properties from one function to another—instead of passing *each* property as a separate parameter, we can just pass the **`Book`** object as a whole.[1] So again, it often makes sense to put associated values *together* into a structure.

Sometimes, however, it makes sense to separate the individual values back *out* of the structure, so that they're stored in individual variables.




This is called **destructuring**.

[1] Although this is convenient, it's also worth considering how many of the object's values are actually needed in the function. When we pass more values than a function needs, it's called **stamp coupling**, and it can limit the reusability of the function. For example, if the function only needs a title, it might be best to pass only the title rather than the whole book object, because then it could work for more than just book titles—perhaps it will also work for movie and song titles.

Of course, we could do this by hand. For example, in the following code, we pull out all six properties from the book object into separate variables, some of which have names that differ from the original properties.

```
val title = book.title
val cost = book.price
val author = book.author
val widthInInches = book.width
val heightInInches = book.height
val isbn = book.isbn
```

*Listing 15.28 - Manually destructuring an object into multiple variables.*

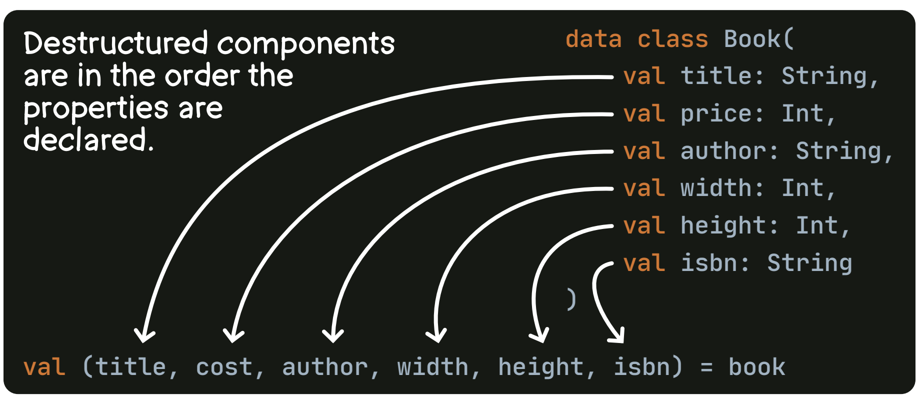
When working with a data class, rather than manually extracting each property to a variable, we can use a **destructuring assignment** to pull out each property to a variable *automatically*. To do this, rather than declaring a *single* variable name, declare multiple variable names with commas, and put them all inside parentheses, like this.

```
val (title, cost, author, widthInInches, heightInInches, isbn) = book
```

*Listing 15.29 - A destructuring assignment.*

This does the same thing as the code in Listing 15.28, but all in a single assignment statement.

Note that the values will be assigned based on the *order* that the properties appear in the primary constructor of the data class. In the case of Listing 15.29 above, this means the `title` variable will be assigned the value of `book.title`, the `cost` variable will be assigned the value of `book.price`, and so forth. Each of the values that come out of a destructuring assignment—title, price, author, and so on—is called a **component**.[1]




Finally, note that we don't have to assign *all* of the components when using a destructuring assignment. For example, if we only need to pull the `title` and `price` out of the `book` object, we can choose to only include two variable names within the parentheses.

```
val (title, cost) = book
```

*Listing 15.30 - Omitting some values from a destructuring assignment.*

[1] The term "component" is broad and can refer to many things within the disciplines of software development and system architecture. Here, we're just using the term in the very narrow context of destructuring.

## Heads Up: Destructuring Risks

When using destructuring assignments, be careful to declare the variables in the correct order. It's easy to mix up the order of the components, such as accidentally swapping the height and width. One way to help mitigate this risk is to declare the types of each component explicitly, like this.

```
val (title: String, cost: Int, author: String) = // ... and so on ...
```

Naturally, this only helps as long as the types of the components are different. For example, in the code above, if we accidentally put **cost** before **title**, we'd get a compiler error, but if we were to accidentally swap **title** and **author**, there would be no error to call our attention to the mix-up!

## Destructuring and the Standard Library

Destructuring doesn't only apply to our own data classes. Some of the types in Kotlin's standard library can also be destructured. For example, back in Chapter 9, we used a class called **Pair**, which can be used with destructuring assignments.

```
val association = "Nail" to "Hammer"
val (hardware, tool) = association
```

*Listing 15.31 - Code from Listing 9.4.*

One of the most common ways to use destructuring is with *lambda parameters*. For example, instead of an individual association, let's say we've got a *map* of the hardware and tools.

```
val toolbox = mapOf(
    "Nail" to "Hammer",
    "Bolt" to "Wrench",
    "Screw" to "Screwdriver"
)
```

*Listing 15.32 - A map of hardware and the corresponding tools.*

When we loop over these tools, the lambda parameter has a type called **Map.Entry**, which has two properties—a **key** and a **value**. Here's how we used it back in Listing 9.20.

```
toolbox.forEach { entry ->
    println("Use a ${entry.value} on a ${entry.key}")
}
```

*Listing 15.33 - Printing the value and key of an* **Entry** *object.*

A **`Map.Entry`** object can be destructured, so instead of using **`entry`** as a parameter for this lambda, we can use parentheses and two variable names, like this.

```
toolbox.forEach { (hardware, tool) ->
    println("Use a $tool on a $hardware")
}
```

*Listing 15.34 - Destructuring an* **`Entry`** *object.*

When we do this, the argument to this lambda will get destructured into two different variables—the first will be the entry's **`key`**, and the second will be the entry's **`value`**.

For example, in Listing 15.34 above, the key will be assigned to a variable named **`hardware`** and the value will be assigned to a variable named **`tool`**.

Destructuring here is a great idea, because **`hardware`** and **`tool`** are terms related to the *problem* that our code solves. We usually say that terms like these are in the **problem domain** or *business domain*.

Contrast these terms with those like *entry*, *key*, and *value*, which are more focused on the data structures that we're using to implement a solution. We often say that those terms are in the **technical domain**.

Next, let's consider the case where we want to print out only the *tools* in the toolbox, but not the corresponding *hardware*. Naturally, we could just do this.

```
toolbox.forEach { (hardware, tool) ->
    println("Found a $tool")
}
```

*Listing 15.35 - Using only one variable from a destructured lambda parameter.*

Here, the **`hardware`** variable is irrelevant to the lambda. A value is assigned to it, but we're not using it, so it's just noise. In other words, it's something we have to read when looking at this code, but it doesn't affect the way the code works.

In cases like this, where one of the components isn't needed, we can substitute an underscore _ for the name of the irrelevant variable.

```
toolbox.forEach { (_, tool) ->
    println("Found a $tool")
}
```

*Listing 15.36 - Using an underscore to avoid creating a variable for the first value when destructuring.*

With that change, we no longer have to concern ourselves with a **`hardware`** variable that isn't used.

## By the Way: Underscores

Underscores are most helpful when we want to *omit* some of the *earlier* components, while *keeping* the *later* components.

For example, if we want to print out only the **`hardware`** instead of only the **`tool`** (the inverse case of Listing 15.36), we *could* use an underscore, like this.

```
toolbox.forEach { (hardware, _) ->
    println("We can service a $hardware")
}
```

However, we don't have to provide a variable for each component, so we could opt to just specify one variable inside the parentheses.

```
toolbox.forEach { (hardware) ->
    println("We can service a $hardware")
}
```

## Destructuring Non-Data Classes

Destructuring isn't limited to data classes. Any object can be destructured, as long as its class includes the right functions. The secret is to add functions named **`component1()`**, **`component2()`**, **`component3()`**, and so on. These are referred to as **`componentN()`** functions.

For example, here's the **`Child`** class from Listing 15.1 at the beginning of this chapter, but this one adds a new property for the child's age.

```
class Child(val name: String, val age: Int)
```

*Listing 15.37 - A simple class that represents a child.*

If we want to add the ability to destructure this class, we don't have to convert it to a data class. Instead, we can simply add functions named **`component1()`** and **`component2()`**, where each one returns one of the properties.

```
class Child(val name: String, val age: Int) {
    operator fun component1() = name
    operator fun component2() = age
}
```

*Listing 15.38 - Adding componentN() functions to the* **`Child`** *class.*

With this, we can now use destructuring to print out the child's name and age.

```
val children = listOf(
    Child("Fiona", 5),
    Child("Jack", 7)
)

children.forEach { (name, age) ->
    println("$name is $age years old.")
}
```

*Listing 15.39 - Destructuring `Child` objects.*

Note that we had to include the `operator` modifier on the two functions in Listing 15.38. This is the first time we've created an **operator function**. When a function includes the `operator` modifier, it can still be called like any other function, but it also serves some special purpose—and the particular purpose that it serves depends upon the name of the function. When a function is named as in Listing 15.38 (i.e., like `componentN()`), that special purpose is that the function will be used when the object is destructured.

## By the Way: Other Operator Functions

Kotlin includes a lot of operator functions that can enhance your classes with new abilities. For example, by including an operator function named `plus()`, your objects will work with the plus sign.

```
val tenDollarBill = fiveDollarBill + fiveDollarBill
```

The full list of operator functions can be found in the official Kotlin documentation.

We can even create an extension function to add destructuring to a class for which we *don't* have the source code. For example, with a little ingenuity, we can create our own extension functions to destructure a `Double` into its integer and fractional parts.

```
operator fun Double.component1() = toString().split(".").first().toInt()
operator fun Double.component2() = toString().split(".").last().toInt()

val (integral, fractional) = 108.245
println(integral)   // 108
println(fractional) // 245
```

*Listing 15.40 - Using extension functions to enable a `Double` object to be destructured.*

So, destructuring can be helpful in certain situations, and data classes are one way to easily add a destructuring capability to our classes!

# Limitations of Data Classes

As we've seen in this chapter, data classes give us a lot of convenience!

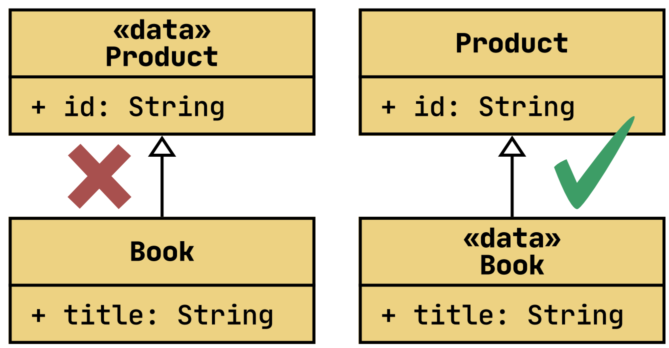
- They create **`equals()`** and **`hashCode()`** functions for *value equality*.
- They create nice-looking **`toString()`** output.
- They make it easy to create copies of an object.
- They can be used with destructuring assignments.

However, we also give up a few things when we declare a class to be a data class, so let's take a quick look at those.

## Data Classes and Inheritance

The first and most significant disadvantage of a data class is that it cannot be extended by another class. In other words, we cannot add the **`abstract`** or **`open`** modifier to a data class.

However, the data class itself *can* extend another class.




Even though a data class can extend another class, it does bring along some trade-offs. If that superclass requires constructor arguments, things get complicated quickly, because of the second disadvantage, which relates to constructor parameters.

## Constructor Parameters

The second disadvantage is that all of the constructor parameters in a data class *must* be property parameters. In other words, each one must be declared with either **`val`** or **`var`**. This means it's not possible to add a constructor parameter that is *only* relayed to a superclass constructor.

```
open class Product(val id: String)

data class Book(id: String, val title: String) : Product(id)
```

*Listing 15.41 - **Error:** Data class primary constructor must only have property (val/var) parameters.*

Also, keep in mind that a data class must have *at least one* parameter in its primary constructor. This makes sense because the benefits of data classes mainly pertain to its properties.

## By the Way: Data Objects

It makes sense that a data class must have at least one *property parameter* in its constructor, because if it has none, then doesn't really have any data to hold. At least, not any data that affects equality, **`toString()`**, **`copy()`**, or destructuring.

However, there are still some particular situations where you might want a data class that has no primary constructor parameters, mainly for parity with other data classes in a sealed type hierarchy (which we'll cover in the next chapter).

For those cases, you can use a **`data object`** instead of a **`data class`**. Although we won't cover them in this book, you can read about data objects in the official Kotlin documentation.

Finally, while a data class *may* have properties that are not part of its constructor, they will not be regarded in any of the functions that are generated. For example, in the following code, the **`serialNumber`** property is not in the primary constructor.

```
data class DollarBill(val amount: Int) {
    var serialNumber: String? = null
}
```

*Listing 15.42 - This data class includes a property that is not part of the primary constructor.*

A property like **`serialNumber`** won't be considered in **`equals()`**, **`hashCode()`**, or **`toString()`** because it's declared in the body of the class, but not in the primary constructor. It won't be possible to call **`copy()`** with it, and it won't be used for destructuring assignments.

To demonstrate this, the following code shows how two **`DollarBill`** objects are considered equal, even though they have different values for the **`serialNumber`**.

```
val bill1 = DollarBill(5).apply { serialNumber = "QB12345678T" }
val bill2 = DollarBill(5).apply { serialNumber = "IE87654321C" }

println(bill1 == bill2) // true, despite different serial numbers
```

*Listing 15.43 - Demonstrating that* **`serialNumber`** *does not affect equality.*

Even with these disadvantages, data classes are tremendously helpful, especially when dealing with immutable classes that are primarily meant to hold properties.

In the next chapter, we'll introduce another class modifier, which will enable us to account for every possible subclass of an interface or abstract class.

# Summary

In this chapter, we learned all about data classes and destructuring, including:

- The difference between reference equality and value equality.
- How to manually override `equals()` and `hashCode()` to achieve value equality.
- How to manually override `toString()` so that our classes work well with `println()`.
- How to declare a data class so that we don't have to manually override `equals()`, `hashCode()`, or `toString()`.
- How to use the `copy()` function to make it easier to create an object based on another object's values.
- How to use a destructuring assignment when working with data classes.
- How to enhance a non-data class to enable destructuring assignments.
- How to use extension functions to enable destructuring assignments.
- Some trade-offs of using data classes.

Let's leave the two girls to enjoy the wildlife at the park, and head somewhere much colder. In the Antarctic, Cecil is about to discover another special kind of class in Kotlin—*sealed classes!*

Kotlin: An Illustrated Guide

Chapter 16

# Sealed Types

## Let’s make the compiler even more helpful by limiting our types!

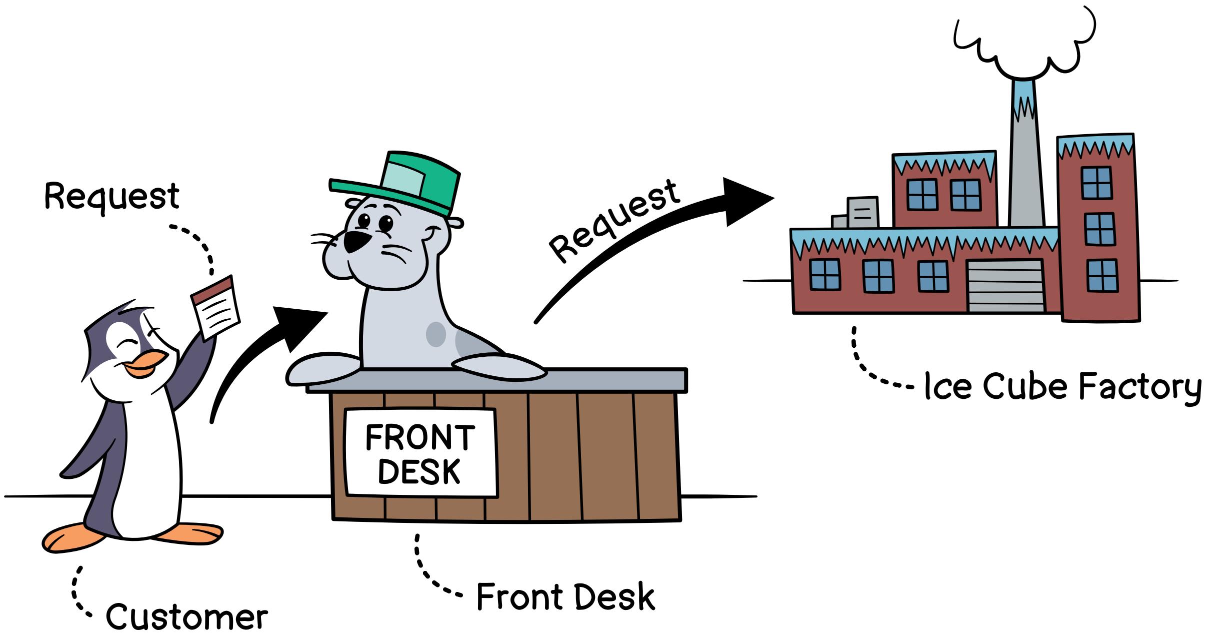
In Chapter 5, we saw how limiting our options can be a good thing. In that chapter, we used enum classes to limit our *values*, which allows Kotlin to ensure that we account for all possibilities in a `when` expression.

We can get a similar benefit for our *types* by using sealed interfaces and classes. In this chapter, we’ll visit *Cecil’s Ice Shop* to learn all about sealed types.

Let’s get started!

In the frigid lands of the Antarctic, there's a store called *Cecil's Ice Shop*, a thriving business where the locals can buy containers of ice cubes in three different sizes.

It's a simple operation—when customers want to place an order or ask for a refund, they show up to the front desk and fill out a request form. From there, the front desk sends the request off to the ice cube factory, which handles the fulfillment.

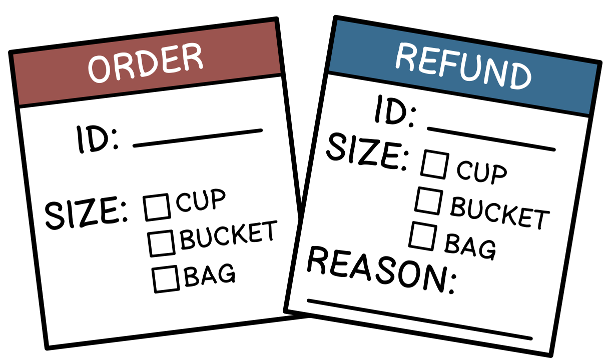



Cecil, the store's owner, is also modeling out his operations in Kotlin code. To start with, he created an enum class to represent those three sizes of ice cube packages.

```
enum class Size { CUP, BUCKET, BAG }
```

*Listing 16.1 - An enum representing three sizes of ice cube packages.*

Next, for the order and refund requests, he created an interface named **`Request`**.




The front desk deals with lots of requests each day, so in order to keep track of them all, each one has a unique ID number. So, he included a property named **`id`** in the **`Request`** interface.

```
interface Request {
    val id: Int
}
```

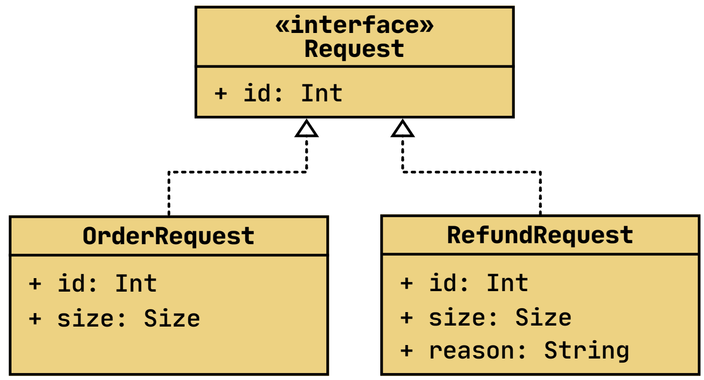
*Listing 16.2 - A simple Request interface with one property.*

Next, he added two classes that implement that interface—one for placing an order, and one for requesting a refund.

```
class OrderRequest(override val id: Int, val size: Size) : Request
class RefundRequest(override val id: Int, val size: Size, val reason: String) : Request
```

*Listing 16.3 - Two classes implementing the Request interface.*

Then, in his Kotlin code, Cecil created a **`FrontDesk`** object to receive a **`Request`**. The front desk records that it received the request by printing out its ID number.




After that, he uses a **`when`** conditional to do a smart cast, and sends the request along to the correct function at the *ice cube factory*, where the request will be fulfilled.

```
object FrontDesk {
    fun receive(request: Request) {
        println("Handling request #${request.id}")
        when (request) {
            is OrderRequest  -> IceCubeFactory.fulfillOrder(request)
            is RefundRequest -> IceCubeFactory.fulfillRefund(request)
        }
    }
}
```

*Listing 16.4 - An object representing the front desk, which can receive requests.*

Speaking of the ice cube factory, Cecil isn't too concerned about exactly *how* it handles orders and refunds. So, in his Kotlin code, he created an **`IceCubeFactory`** object that just prints out a message as each request is being fulfilled.

```
object IceCubeFactory {
    fun fulfillOrder(order: OrderRequest) = println("Fulfilling order #${order.id}")
    fun fulfillRefund(refund: RefundRequest) = println("Fulfilling refund #${refund.id}")
}
```

*Listing 16.5 - An object representing the ice cube factory, which prints out the orders that it receives.*

With this simple Kotlin code, a customer can now order a cup of ice! The front desk receives the order and forwards it to the ice cube factory for fulfillment.

```
val order = OrderRequest(123, Size.CUP)
FrontDesk.receive(order)
```

*Listing 16.6 - Passing an order to the front desk, which is forwarded to the factory.*

Cecil's code also allows a customer to request a refund, simply by giving the front desk a refund request.

```
val refund = RefundRequest(456, Size.CUP, "Accidentally ordered too much")
FrontDesk.receive(refund)
```

*Listing 16.7 - Passing a refund request to the front desk, which is forwarded to the factory.*

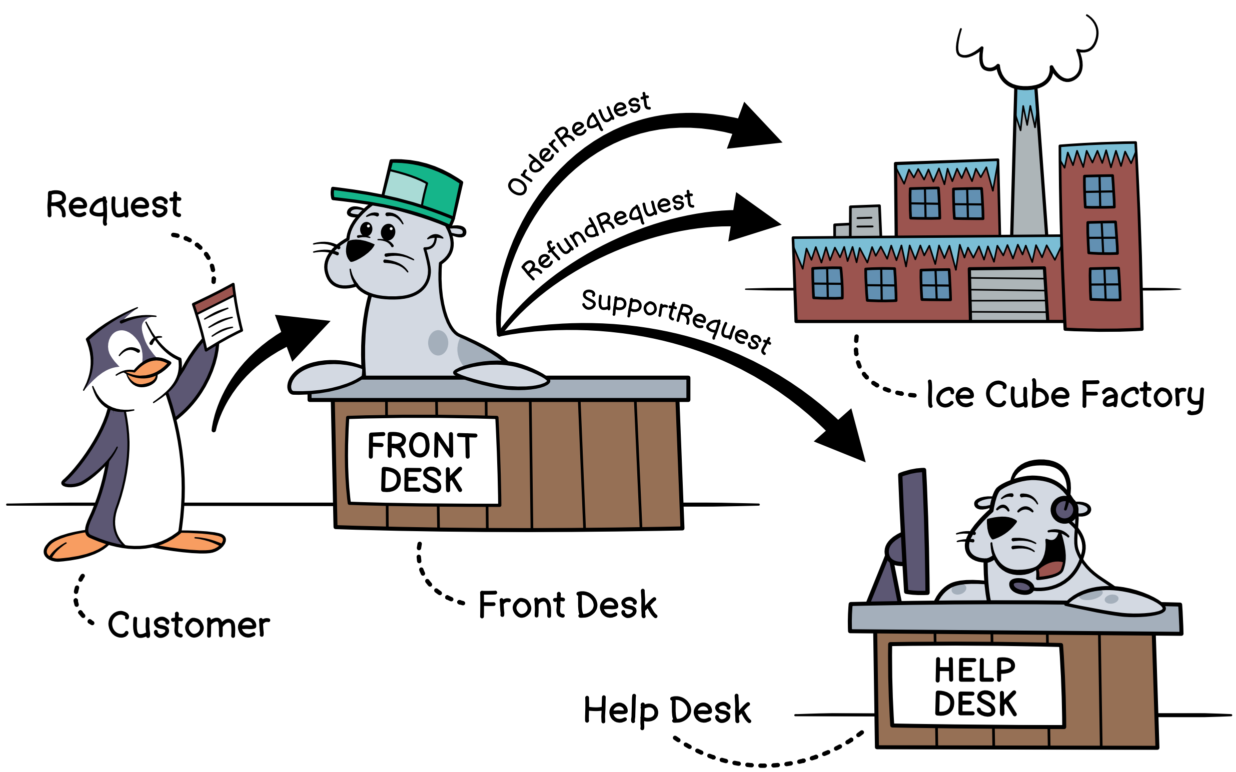
With this code, Cecil's Ice Shop continued fulfilling orders and refunds, making many satisfied customers… until one day when Cecil needed to add one more request type!

## Adding Another Type

One day, a customer named Wallace needed help opening his bag of ice. With that massive body and those slippery flippers, it's hard to blame a walrus for not being able to open that bag!


Cecil decided that it was time to start offering customer support. In order to help customers like Wallace, Cecil came up with plans to add a new kind of request, called a *support request*.

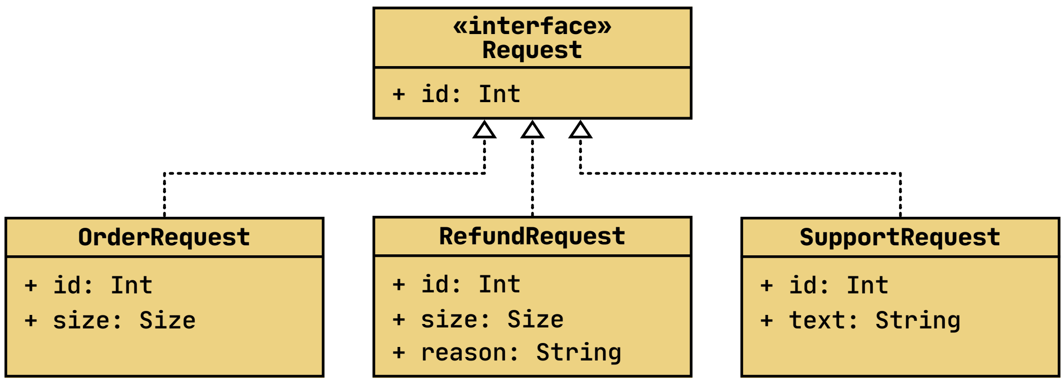
A customer who needs help could just fill out a support request with text about the problem, and hand it to the front desk. The front desk would forward it on to a new *help desk*.



Naturally, it was easy for Cecil to add a new request type in his Kotlin code. He just created a new class called **`SupportRequest`**, which implemented the **`Request`** interface. In addition to the **`id`** property, this new class added only a **`text`** property, where customers can write a description of the help that they need.

```
class SupportRequest(override val id: Int, val text: String) : Request
```

*Listing 16.8 - A third class that implements the Request interface.*




As with the ice cube factory, instead of including details about how the help desk *actually* helps, Cecil's code simply included a **`println()`** statement to log that the request was received.

```
object HelpDesk {
    fun handle(request: SupportRequest) = println("Help desk is handling ${request.id}")
}
```

*Listing 16.9 - An object that handles* **`SupportRequest`** *objects. Here it just prints out that it was received.*

Great! Cecil hit the "Run" button in his IDE, and his shop was up and running again. Wallace submitted his help request, and was told that someone from the help desk would follow up with him.

```
val request = SupportRequest(789, "I can't open the bag of ice!")
FrontDesk.receive(request)
```

*Listing 16.10 - Passing a support request to the front desk.*

A few days later, though, Wallace returned, as grumpy as ever. "Why hasn't anyone contacted me about my support request?" he asked.

Embarrassed, Cecil combed through his program's output for Wallace's support request ID number to see what happened. To his surprise, he only found one line about it.

```
Handling request #789
```

"The front desk recorded that it received the request, but that was all! The help desk apparently never received it!" noted Cecil. What had happened? He pulled up the code for the front desk again.

```
object FrontDesk {
    fun makeRequest(request: Request) {
        println("Handling request #${request.id}")
        when (request) {
            is OrderRequest -> IceCubeFactory.fulfillOrder(request)
            is RefundRequest -> IceCubeFactory.fulfillRefund(request)
        }
    }
}
```

*Listing 16.11 - The front desk does not include a* `when` *branch for* `SupportRequest`*.*

"Of course!" he cried, "I forgot to add a branch to the `when` conditional for the new `SupportRequest` type!" He would have slapped his forehead, but his flipper couldn't reach his head.

Cecil noticed how easy it is to forget to add a branch to his `when` conditional when he adds a new subtype. He mused, "I've only got *one* `when` conditional in my code right now. How much *easier* would it be to forget a branch if I had even *more* of them scattered throughout my code? Too bad I didn't catch this problem until a *customer* complained about it!"

Instead of waiting for a customer to report a problem with his code, it'd be great if Cecil could find out sooner. He *could* add an `else` branch that prints out that a branch is missing. But even with that, he wouldn't know until his code is *running*.

What if Kotlin could tell him right away, with a compile-time error message? In other words, if he forgets to add a branch to a `when`, he'd love to know *before* the code ever runs—and *well before* any customer could be affected! Thankfully, Kotlin has a feature that can solve this problem!

# Introduction to Sealed Types

As you might recall, when a conditional accounts for *every* possible case, then we say that the conditional is exhaustive. As we saw back in Chapter 5, we can use enum classes to ensure that our `when` conditionals are exhaustive.

For example, if Cecil wants to describe the different sizes of ice packages, he can write something like this.

```
when (size) {
    Size.CUP    -> println("A 12-ounce cup of ice")
    Size.BUCKET -> println("A bucket with 1 quart of ice")
    Size.BAG    -> println("A bag with 1 gallon of ice")
}
```

*Listing 16.12 - An exhaustive* `when` *conditional.*

If one of these branches were missing from this **`when`** statement, then Kotlin would give a compiler error.

```
when (size) {
    Size.CUP    -> println("A 12-ounce cup of ice")
    Size.BAG    -> println("A bag with 1 gallon of ice")
}
```

*Listing 16.13 - **Error:** "**`when`** expression must be exhaustive, add necessary **`BUCKET`** branch or **`else`** branch" (does not compile).*

This is exactly the kind of compiler error that Cecil would love to see, but instead of a **`when`** conditional that checks the *value* of a variable, his **`when`** conditional is checking the *type* of a variable.

```
when (request) {
    is OrderRequest  -> IceCubeFactory.fulfillOrder(request)
    is RefundRequest -> IceCubeFactory.fulfillRefund(request)
}
```

*Listing 16.14 - How can we get this **`when`** conditional to create a similar compiler error?*

So, how can Cecil tell Kotlin that he wants this **`when`** statement to be exhaustive, to make sure that there's a branch for each subtype of the **`Request`** interface? The secret is to use a feature called a **sealed type**. Using a sealed type is easy—we just add the **`sealed`** modifier to our interface or class declarations.

To demonstrate this, let's update Cecil's **`Request`** interface so that it's sealed. The **`sealed`** modifier goes just before the **`interface`** keyword, as shown here.

```
sealed interface Request {
    val id: Int
}
```

*Listing 16.15 - Updating the **`Request`** interface so that it's a sealed interface.*

When a type like **`Request`** is sealed, Kotlin will keep track of all its direct subtypes. That way, Kotlin can know when we've been exhaustive in a conditional that checks subtypes. In fact, just by adding the **`sealed`** modifier to the **`Request`** interface, it caused a compiler error on the **`when`** statement.

```
object FrontDesk {
    fun receive(request: Request) {
        println("Handling request #${request.id}")
        when (request) {
            is OrderRequest  -> IceCubeFactory.fulfillOrder(request)
            is RefundRequest -> IceCubeFactory.fulfillRefund(request)
        }
    }
}
```

*Listing 16.16 - **Error:** '**`when`**' expression must be exhaustive, add necessary '**`is SupportRequest`**' branch or '**`else`**' branch instead.*

Perfect! Just like Cecil wanted, Kotlin now alerts him when he forgets a branch, and since he gets this alert at compile time, he can fix it before any customers are affected. Speaking of fixing it, that's also easy to do—just by adding a branch for **`SupportRequest`**, the compiler error goes away.

```
object FrontDesk {
    fun receive(request: Request) {
        println("Handling request #${request.id}")
        when (request) {
            is OrderRequest  -> IceCubeFactory.fulfillOrder(request)
            is RefundRequest -> IceCubeFactory.fulfillRefund(request)
            is SupportRequest -> HelpDesk.handle(request)
        }
    }
}
```

*Listing 16.17 - Adding a branch for* **`SupportRequest`** *fixes the compiler error.*

For what it's worth, this compiler error can also be avoided by using an **`else`** branch. However, in the code above, Cecil needs the smart cast in order to send it to the help desk.

And now, the help desk is receiving support requests! Cecil can rest easy, knowing that the help desk is taking care of customers like Wallace.

# Sealed Classes

In the example above, we added the **`sealed`** modifier to an *interface* declaration. However, it's also possible to add it to a *class* declaration. For example, instead of requiring customers to enter an **`id`** number on each request, Cecil could change **`Request`** to an abstract class and automatically assign a random number to it. Since interfaces can't hold state, Cecil would need to change the interface to a class, like this.

```
sealed class Request {
    val id: Int = kotlin.random.Random.nextInt()
}
```

*Listing 16.18 - Converting a sealed interface to a sealed class.*

With this simple change, he's now using a sealed class instead of a sealed interface. Naturally, this change implies a few updates to the subclasses—like removing the **`id`** property and calling **`Request`**'s constructor.

```
class OrderRequest(val size: Size) : Request()
class RefundRequest(val size: Size, val reason: String) : Request()
class SupportRequest(val text: String) : Request()
```

*Listing 16.19 - Updating the subtypes so that they extend the* **`Request`** *class (instead of implementing the old* **`Request`** *interface).*

Note that a `sealed class` is, by definition, also an `abstract class`. This means that we can't directly instantiate it—we can only instantiate one of its subclasses. Although it's not an error to include *both* the `sealed` and `abstract` modifiers on the same class, doing so is redundant and unnecessary. So if you use the `sealed` modifier, omit the `abstract` modifier.

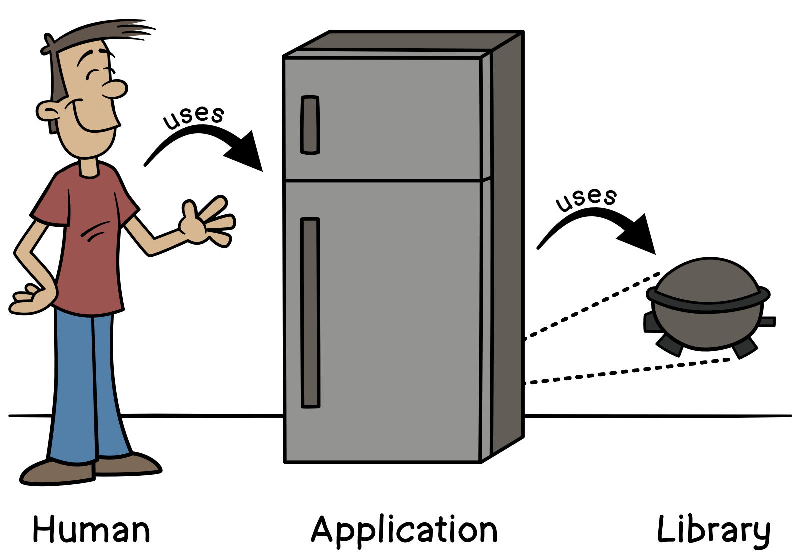
## Why Is the `sealed` Modifier Required At All?

Now, you might be wondering why we need to add the `sealed` modifier to our interface or class declaration. Why can't Kotlin be exhaustive in those `when` statements without it? We'll answer that question, but first, let's talk about refrigerators.

You probably use a refrigerator all the time. You make sure it's plugged in, then you open the door, put something inside for the refrigerator to keep cold, and then you close the door again. A refrigerator is a household *appliance*—it's a piece of equipment that's designed for *humans* to interact with.

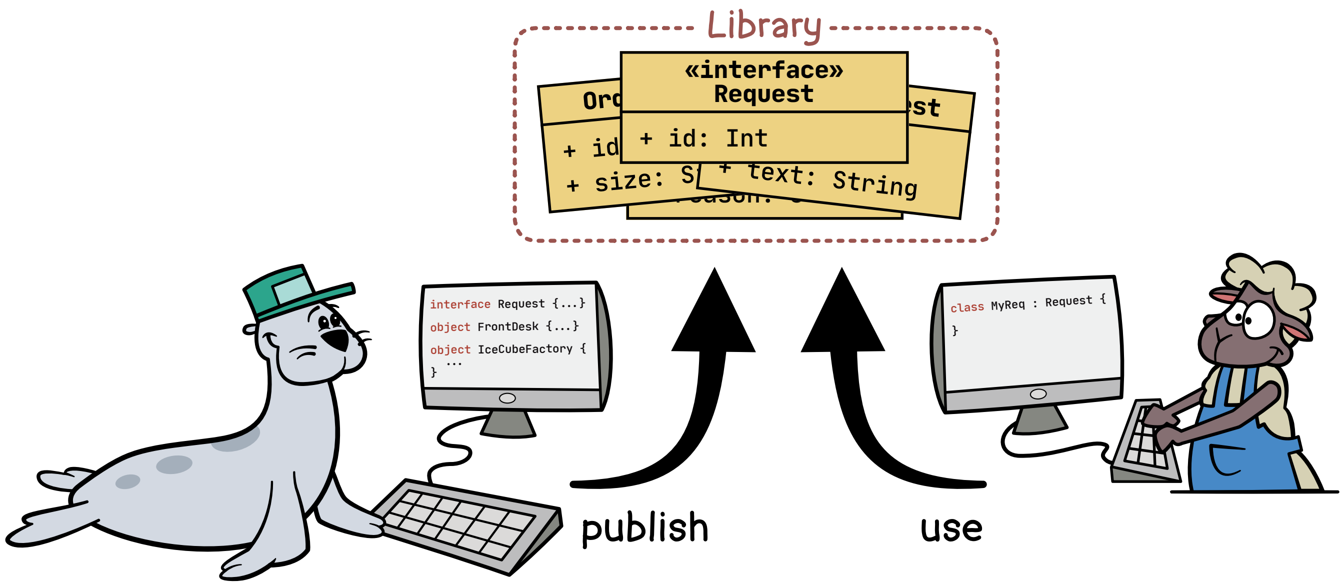
Now consider a *compressor*. A compressor is a major *component* of a refrigerator. Without it, a refrigerator won't keep your food cold. However, as a human, you don't *directly* interact with a compressor. *You* use a refrigerator, and the *refrigerator* uses its compressor.

Similar to refrigerators, some code that we write is intended for a *human* to interact with directly. Instead of calling this kind of software an *appliance*, we call it an **application**. On the other hand, similar to a compressor, *other* programs that we write are not intended to be used directly by humans—it's intended that they'll be used as a *component* of an application. This kind of software component is called a **library**.




Throughout this book, we've already been using a library called the *standard library*. This library includes basic classes and interfaces, functions that we used for collection processing, and lots more. In fact, just like you can't do much with a refrigerator if it's missing its compressor, you can't do much with a Kotlin project if you don't include the standard library!

It's also possible to create a library from your *own* code, so that other developers can use it. For example, Cecil could take his code, compile it, and bundle it up into a library that includes his **`Request`** interface, its subclasses, and the **`FrontDesk`** and **`IceCubeFactory`** objects.




Then, if Bert from *Bert's Snips & Clips* (see Chapter 7) wants to use that interface, he could include Cecil's library in his code.

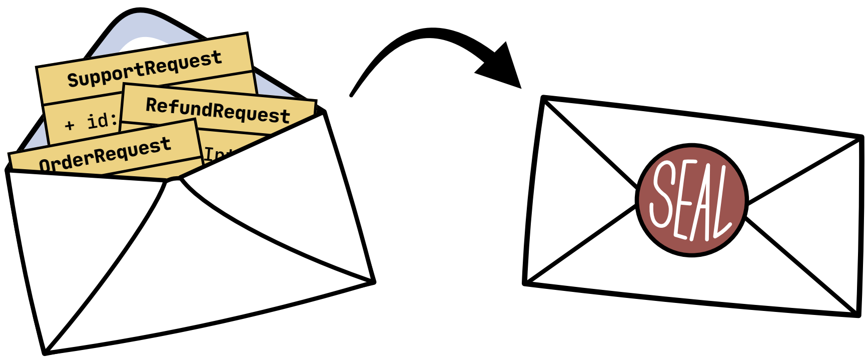
When Bert uses Cecil's library, he'd be able to see that there's a **`Request`** interface, and could create his *own* subclass of it. For example, he might create a **`SubscriptionRequest`**, where his customers could subscribe to his mailing list for coupons!

However, the library was *already compiled* before Bert started using it. So, if the **`FrontDesk`** code assumes there would only be *three* subclasses (because that's how many there were when it was compiled) but Bert creates a fourth, then there could be a new case that the **`when`** conditional would know nothing about.

*At the point when Cecil builds his library*, there's no way for Kotlin to know all of the subclasses that Bert—or any other developers—might also create in the future when *using* that library.

So instead, by adding the **`sealed`** modifier to the interface, it prevents Bert from being able to add another subtype of **`Request`** when he uses the library. *Cecil* can still add one, of course, but anyone *using* the library will be unable to do so.

Marking **`Request`** as **`sealed`** is kind of like taking its three subclasses, putting them in an envelope, and then "sealing" the envelope so that anyone else who gets that envelope can't put anything else inside!




In summary, when we want exhaustive subtype matching, we'll need to include the `sealed` modifier, regardless of whether we're building an application or a library.

## Restrictions of a Sealed Type's Subtype

As we've seen, sealed types are helpful when we want Kotlin to ensure that we exhaustively match subtypes in a `when` conditional. By design, they come with a few restrictions. Specifically, every direct subtype of a sealed interface or class:

1. Must be declared in the same *code base*. In other words, if we were to create a library out of our code, anyone using that library would be working in a *different* code base, and would *not* be able to subtype it.

2. Must be declared in the same *package*. Even in the same Kotlin project, the subtypes of a sealed type must all be in the same exact package as the sealed type itself.

For what it's worth, these rules are relaxed compared to what they were back in Kotlin 1.0. Back then, only sealed *classes* were supported (sealed *interfaces* were added in Kotlin 1.5), and all subclasses had to be declared *inside the class body* of the sealed class!

Note that these limitations apply only to *direct* subtypes of the sealed type. We *can* create a subtype of a subtype of a sealed type, even if the sealed type is in another library.

This class is sealed, so its subtypes must be in the same code base and package.

```
sealed class Request {
    val id: Int = kotlin.random.Random.nextInt()
}
```

However, these subclasses are not sealed, so their subtypes are not subject to those restrictions.

```
open class OrderRequest(...) : Request()
open class RefundRequest(...) : Request()
open class SupportRequest(...) : Request()
```

For example, Bert can't create a new *direct* subtype of `Request`. However, he could create a subclass of `SupportRequest`, as long as Cecil had marked it as open or abstract. Why are *direct* subtypes restricted but *secondary* subtypes allowed?

Well, let's look at the **`FrontDesk`** code again.

```
object FrontDesk {
    fun receive(request: Request) {
        println("Handling request #${request.id}")
        when (request) {
            is OrderRequest   -> IceCubeFactory.fulfillOrder(request)
            is RefundRequest -> IceCubeFactory.fulfillRefund(request)
            is SupportRequest -> HelpDesk.handle(request)
        }
    }
}
```

*Listing 16.20 - The* **`FrontDesk`** *code from Listing 16.17.*

Let's say Bert is using Cecil's library, and he adds a new *direct* subtype of **`Request`**, named **`SubscriptionRequest`**. In this code, if **`FrontDesk.receive()`** is called with an instance of **`SubscriptionRequest`**, *none* of the branches in this **`when`** conditional would match, so this conditional wouldn't *actually* be exhaustive. That's why Kotlin doesn't allow that.

```
object FrontDesk {
    fun receive(request: Request) {           If this could be a SubscriptionRequest...
        println("Handling request #${request.id}")
        when (request) {
            is OrderRequest    -> IceCubeFactory.fulfillOrder(request)
            is RefundRequest  -> IceCubeFactory.fulfillRefund(request)
            is SupportRequest -> HelpDesk.handle(request)
        }                                     ...then none of these cases would match!
    }
}
```

Now, let's say he creates a subtype of **`SupportRequest`** called **`CouponSupportRequest`**. In this case, when **`FrontDesk.receive()`** is called with an instance of **`CouponSupportRequest`**, then the third branch would match, because **`CouponSupportRequest`** is a more specific kind of **`SupportRequest`**. So, the conditional is still exhaustive in this situation.

So again, the two restrictions above apply only to *direct* subtypes, because secondary subtypes won't break the integrity of the conditionals.

## Sealed Types vs Enum Classes

As mentioned earlier, it was way back in Chapter 5 that we first saw how Kotlin could tell us when our **`when`** conditionals are exhaustive, without the need for an **`else`** branch, as shown here.

```kotlin
enum class SchnauzerBreed { MINIATURE, STANDARD, GIANT }

fun describe(breed: SchnauzerBreed) = when (breed) {
    SchnauzerBreed.MINIATURE -> "Small"
    SchnauzerBreed.STANDARD  -> "Medium"
    SchnauzerBreed.GIANT     -> "Large"
}
```

*Listing 16.21 - Combines the code from Listings 5.4 and 5.8.*

And as we've seen in *this* chapter, Kotlin can do the same thing for sealed types.

```kotlin
when (request) {
    is OrderRequest   -> IceCubeFactory.fulfillOrder(request)
    is RefundRequest  -> IceCubeFactory.fulfillRefund(request)
    is SupportRequest -> HelpDesk.handle(request)
}
```

*Listing 16.22 - Exhaustive matching for sealed types.*

After noticing that similarity, it's tempting to think of sealed types as a more sophisticated kind of enum class, but that comparison can be misleading. Sealed types and enum classes have some critical differences that are important to know.

First, there's a difference between *what the conditional is checking*. With a sealed type, your conditional is checking *subtypes* of the sealed type.

```kotlin
when (request) {
    is OrderRequest   -> IceCubeFactory.fulfillOrder(request)
    is RefundRequest  -> IceCubeFactory.fulfillRefund(request)
    is SupportRequest -> HelpDesk.handle(request)
}
```

These are all subtypes of Request

Note the "is" keyword

With an enum class, on the other hand, the conditional is not checking *types*—it's checking *values*.

```kotlin
fun describe(breed: SchnauzerBreed) = when (breed) {
    SchnauzerBreed.MINIATURE -> "Small"
    SchnauzerBreed.STANDARD  -> "Medium"
    SchnauzerBreed.GIANT     -> "Large"
}
```

These are all instances

That's because each entry inside an enum class is an *object*, not a *class*.

```
enum class SchnauzerBreed { MINIATURE, STANDARD, GIANT }
```

This is the type

These are object instances of that type

Second, enum classes have a variety of built-in properties and functions that sealed classes don't have. For example:

- You can get the **`ordinal`** property of an enum entry, but subtypes of a sealed type have no order.
- Enum classes provide the **`entries`** property, which allows us to easily iterate over its entries. A sealed type has no such property for its subtypes.[1]

For these reasons, it's best *not* to think of sealed types as a more sophisticated kind of enum class. They achieve a similar effect in conditionals, but otherwise, they have different characteristics that give each an advantage in different situations.

If you find yourself trying to decide between using a sealed type or an enum class, ask yourself what it is that you're trying to limit. If you need to limit *values*, then use an enum class. If you need to limit *types*, then use a sealed type.

Let's take the example of schnauzer dog breeds from Chapter 5. If we want to represent the three valid *breeds* of a schnauzer, then an enum class works well. The *type* is just **`SchnauzerBreed`**, and its values are *limited* to **`MINIATURE`**, **`STANDARD`**, and **`GIANT`**.

```
// SchnauzerBreed instances are limited to three:
enum class SchnauzerBreed { MINIATURE, STANDARD, GIANT }
```

*Listing 6.23 - An enum class is a good choice for representing a schnauzer breed.*

On the other hand, if we want to represent actual *schnauzers*—that is, the dogs themselves rather than the breed—then a sealed type could be a better choice. This allows us to *limit the types* to just three subtypes.

```
// Subtypes of Schnauzer are limited to three:
sealed class Schnauzer(val name: String, val sound: String)
class MiniatureSchnauzer(name: String) : Schnauzer(name, "Yip! Yip!")
class StandardSchnauzer(name: String) : Schnauzer(name, "Bark!")
class GiantSchnauzer(name: String) : Schnauzer(name, "Ruuuuffff!")
```

*Listing 16.24 - A sealed type is a good choice for representing individual schnauzer dogs.*

[1] Generally, you shouldn't need to iterate over the subtypes of a sealed type. Technically, however, it's possible to do with Kotlin's reflection library.

However, we can still create an *unlimited* number of *instances*.

```
// No limit on how many Schnauzer instances you can create:
val dogs = listOf(
    MiniatureSchnauzer("Shadow"),
    StandardSchnauzer("Agent"),
    MiniatureSchnauzer("Scout"),
    GiantSchnauzer("Rex"),
    GiantSchnauzer("Brutus")
    // ... as many as you want ...
)
```

*Listing 16.25 - Creating multiple instances of different schnauzer breeds.*

Both enum classes and sealed types are important. Each one serves a distinct purpose.

# Summary

Well, Cecil's Ice Shop is doing great now—handling orders, refunds, and even support tickets!

In this chapter, we learned:

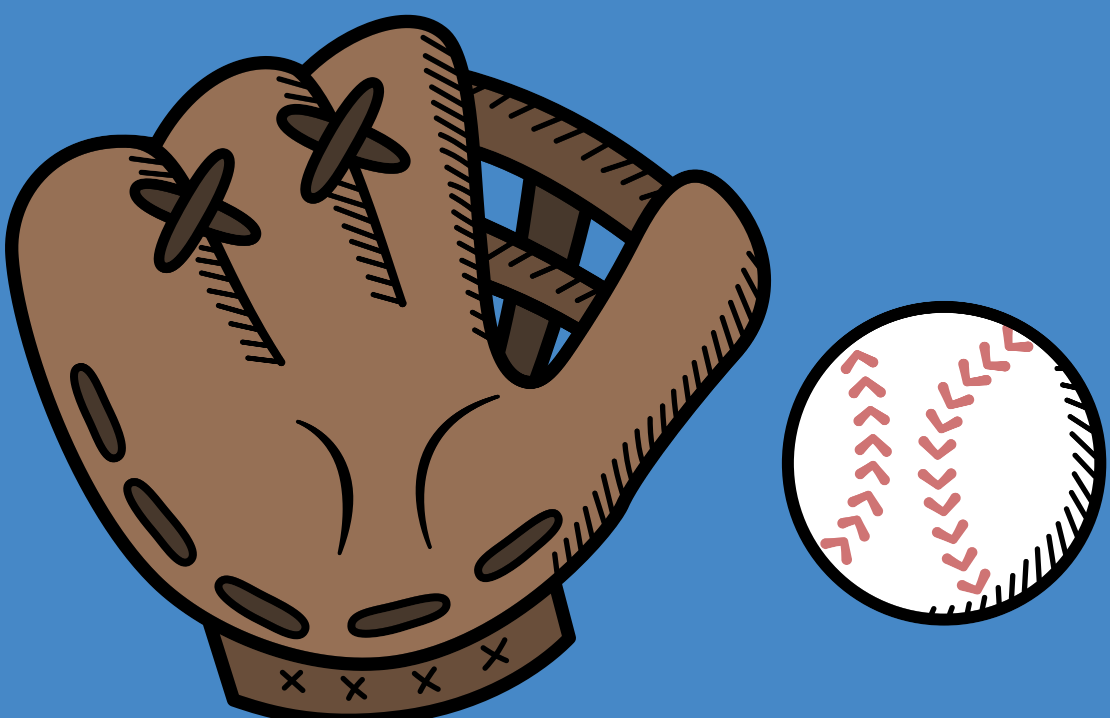
- How normal types will *not* be exhaustively matched in a conditional.
- How sealed types *will* be exhaustively matched in a conditional.
- Why Kotlin requires us to use the `sealed` modifier for this feature.
- How the `sealed` modifier can be applied to both `interface` and `class` declarations.
- The restrictions imposed on the subtypes of sealed types.
- The differences between sealed types and enum classes.

In this chapter, we saw how helpful it is for Kotlin to highlight mistakes at *compile time*. But what about errors that only show up when the code is running? In the next chapter, we'll explore ways to handle those gracefully, so that our program keeps moving forward—even when things go off the rails!

Kotlin: An Illustrated Guide

Chapter 17

# Handling Runtime Exceptions



## That’s a good plan… but what happens when something goes wrong?

In real life, when we decide to do something, we primarily think in terms of a successful experience. For example, if you’re driving to your friend’s house for dinner, you might look up the directions on a mapping app, make sure you’ve got enough gasoline in the car, and leave at the right time in order to arrive when dinner is hot. If everything goes according to plan, you’ll arrive on time.

Things don’t always go according to plan, though. If you get a flat tire while you’re on the way, you’ll have to replace it with the spare, get to a garage, and buy a new tire. By the time you do all of that, dinner could be cold, and you might even have to cancel your plans.

Things can go wrong in our Kotlin code, too. In this chapter we’ll learn how to handle problems that arise while our program is running!

Much like in real life, when our Kotlin code runs, things might not go according to plan. Our functions usually represent our plan–we tell Kotlin, "In general, follow this plan." If anything goes wrong, then we'll do something else, as an *exception* to that plan.

For this reason, when something unexpected happens in our code, we call it an **exception**. In this chapter, we'll learn all about how we can handle those exceptions!

# Problems at Runtime

We've seen how we can get errors at two different times—either at compile time or runtime. As Cecil discovered in the last chapter, errors at compile time are quite helpful, because we can fix them before someone *using* our application can run into it.

However, not every problem can be detected at compile time. For example, here's a function that can convert a number (e.g., 3) to its ordinal (e.g., "third").

```
val ordinals = listOf("zeroth", "first", "second", "third", "fourth", "fifth")
fun ordinal(number: Int) = ordinals.get(number)
```

*Listing 17.1 - This code includes a potential problem that cannot be detected at compile time.*

Looking at this function, it's easy to see that it only supports ordinals for numbers up to 5. However, there's no way the Kotlin compiler can be sure that the `number` argument will be within those bounds. We can easily call this function with a number that's too high.

```
fun main() {
    val place = ordinal(9)
}
```

*Listing 17.2 - Passing an out-of-bounds index.*

Running this `main()` function results in the following error message.

```
Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException: Index 9 out of
bounds for length 6
    at java.base/java.util.Arrays$ArrayList.get(Arrays.java:4165)
    at MainKt.ordinal(Main.kt:3)
    at MainKt.main(Main.kt:7)
    at MainKt.main(Main.kt)
```

The *plan* was to simply return the ordinal for the number, but things didn't go according to plan. Passing `9` to this function resulted in an *exception* to the plan. Since the *compiler* can't prevent us from calling `ordinal()` with an argument that's out of bounds, we'll have to handle this problem at *runtime* instead.

There are many similar problems that can't be detected at compile time. For example:

- At compile time, Kotlin can't know whether a map will include a particular key. (See Listing 9.11).
- At compile time, Kotlin can't know what values we might get when we ask a database for data.
- At compile time, Kotlin can't know what a user might type into the keyboard when prompted. We could ask the user for a zip code, but might get a phone number instead.

Because of this, we need to know how to handle the things that can go wrong at runtime. To do that, we first need to understand the *call stack*.

## The Call Stack

When a Kotlin program is running, code in one place usually calls code in another place, which in turn might call code in yet another place.

To demonstrate this, let's add a function that will *announce* the ordinal of a task that we're planning to do. Instead of naming this function **`announce()`**, we'll abbreviate it to **`annc()`**, which will fit better on some of the diagrams that we'll see in a moment.

```kotlin
val ordinals = listOf("zeroth", "first", "second", "third", "fourth", "fifth")
fun ordinal(number: Int) = ordinals.get(number)

fun annc(number: Int, task: String): String {
    val ordinal = ordinal(number)
    return "The $ordinal thing I will do is $task."
}

fun main() {
    val first = annc(1, "clean my room")
    // "The first thing I will do is clean my room."
}
```

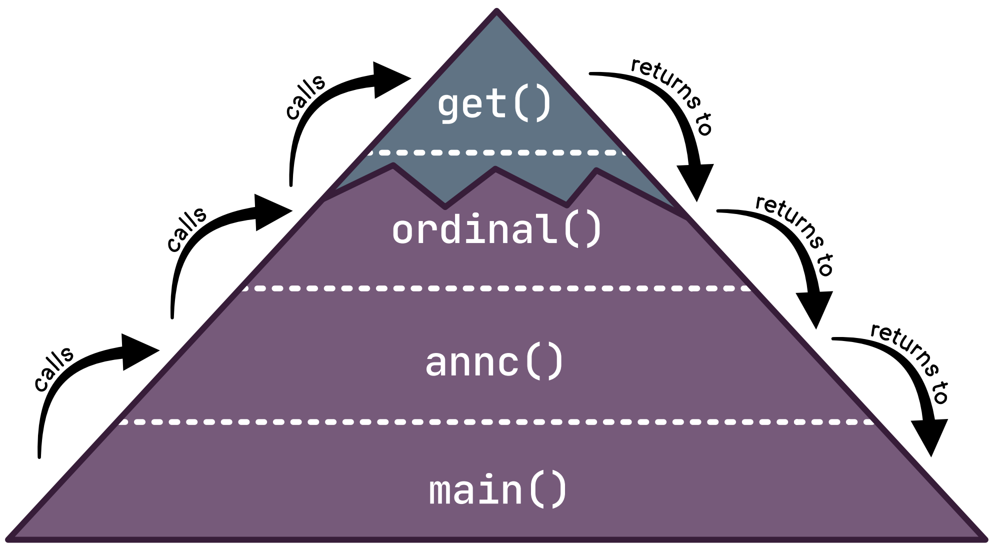
*Listing 17.3 - One function calls another, which calls another…*

This code has a simple execution path. Starting in the **`main()`** function:

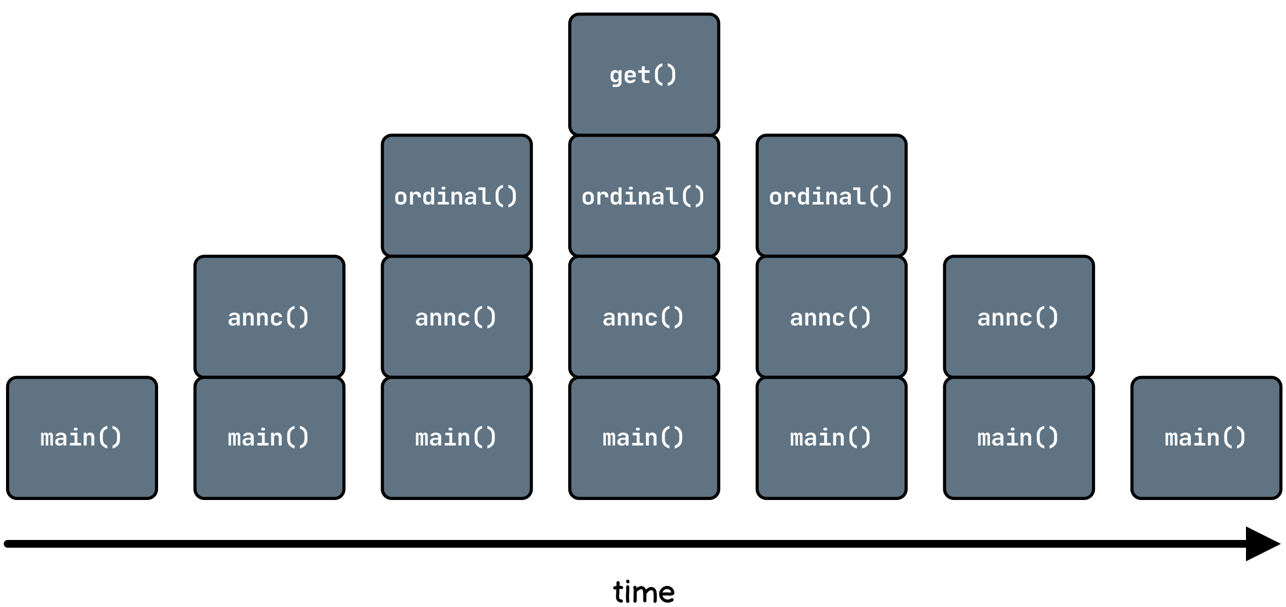
1. The **`main()`** function calls the **`annc()`** function.
2. The **`annc()`** function then calls the **`ordinal()`** function.
3. The **`ordinal()`** function calls the **`get()`** function of the list.
4. The **`get()`** function returns its result to the **`ordinal()`** function.
5. The **`ordinal()`** function returns its result to the **`annc()`** function.
6. The **`annc()`** function returns its result to the **`main()`** function.

And of course, when the **`main()`** function ends, the program successfully finishes running.

It's kind of like our program is climbing a mountain. It starts inside the **`main()`** function at ground level, and for each function call along the way, it climbs higher on the mountain. Eventually, it's in the **`get()`** function, at which point each function returns its value in turn, as the program works its way back down the mountain, back into the **`main()`** function.



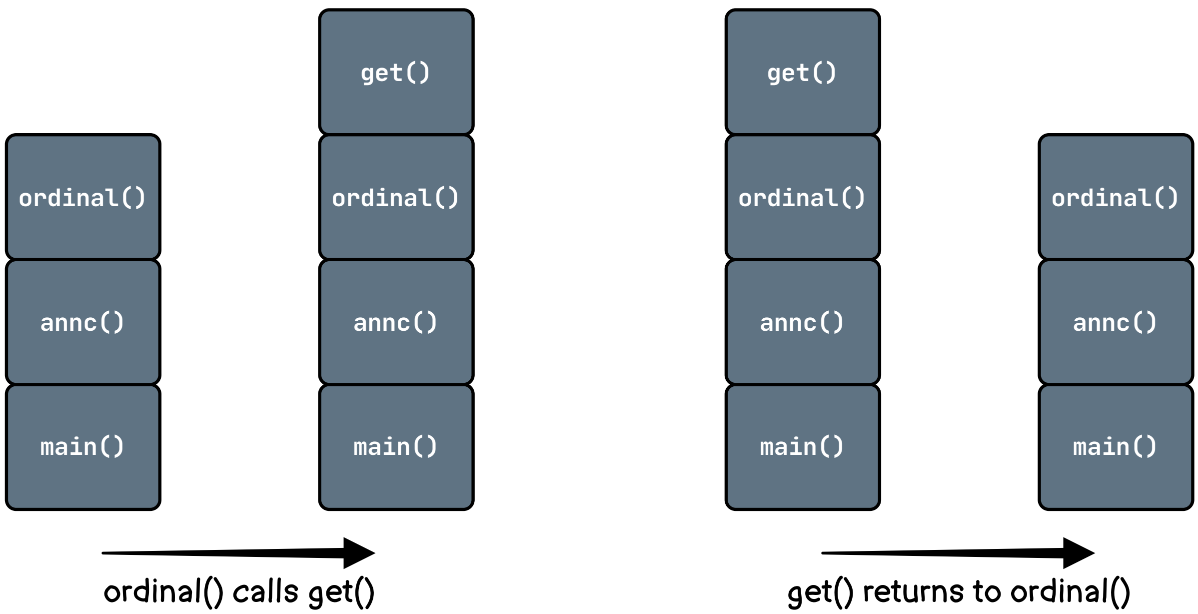

Rather than drawing it as a mountain, we can depict it as a simple stack of boxes, like this.




The diagram above still roughly has the shape of a mountain. Each little box represents a function. As the program's execution progresses (from left to right in this diagram), each function either *calls* another function, or it *returns* a value to the function that called it.

When one function calls another, the pile of boxes at the next step will *include* that next function on top of the one that called it.

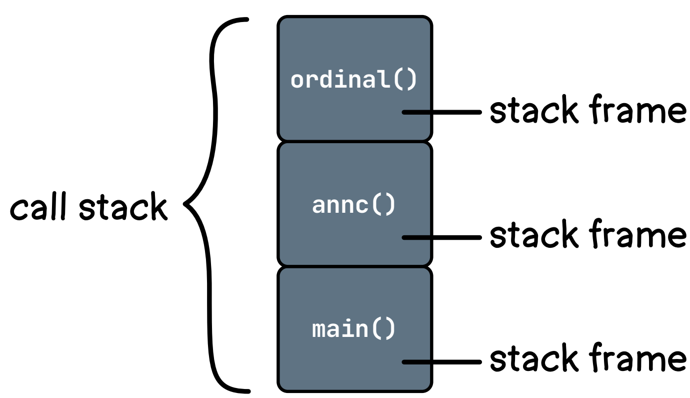
And when a function returns, the pile of boxes at the next step will *remove* that function from the top of the stack.




Note that those are the *only* two ways that the stack will change! A box can never be added or removed from anywhere except the *top* of the stack!

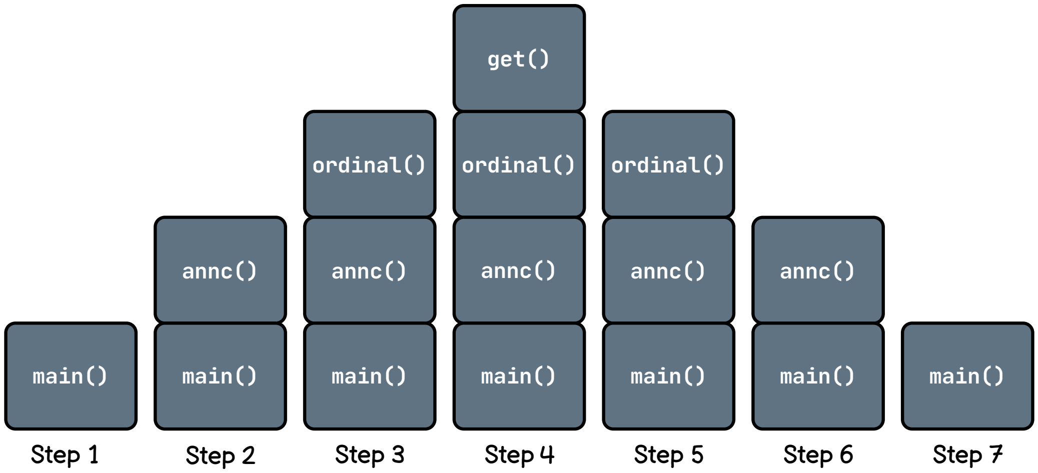
In programming terms:

- This stack of function calls is referred to as the **call stack**, or sometimes just **the stack**.
- Each box in the stack is a **stack frame**.




The diagram on the next page shows what the call stack looks like at each step as the program is running.

Our example from Listing 17.3 is pretty simple—we just have a few functions, each calling the next, so over time, the call stack looks like a single mountain.



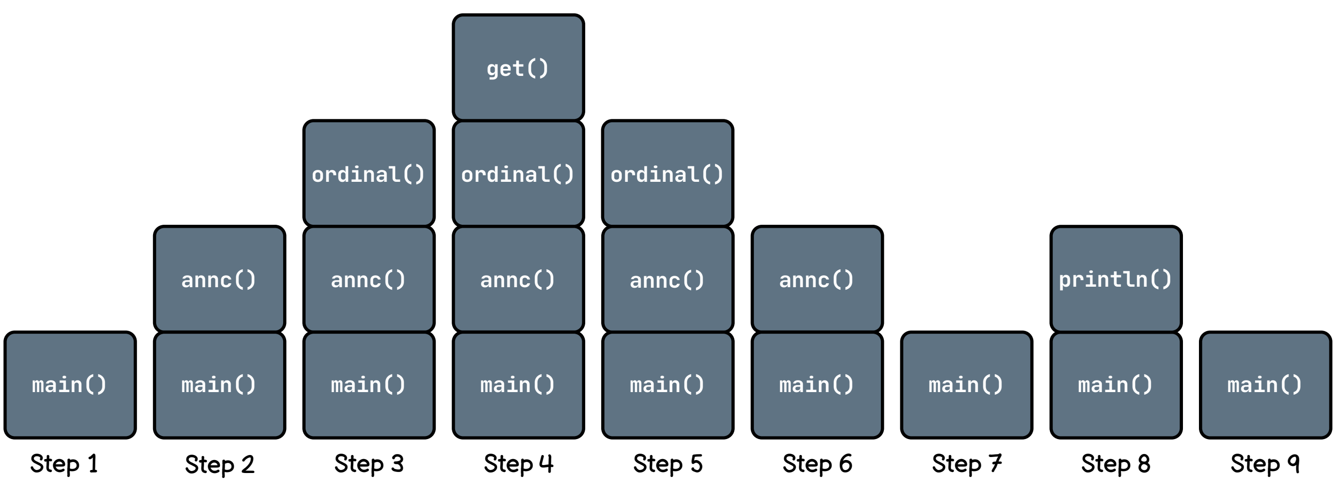

Usually, though, it'll look more like a mountain range. For example, let's add a call to **`println()`** in the **`main()`** function.

```
fun main() {
    val first = annc(1, "clean my room")
    println(first)
}
```

*Listing 17.4 - Adding a call to* **`println()`**.

```
The first thing I will do is clean my room.
```

With this small change, the call stack over time looks like this.

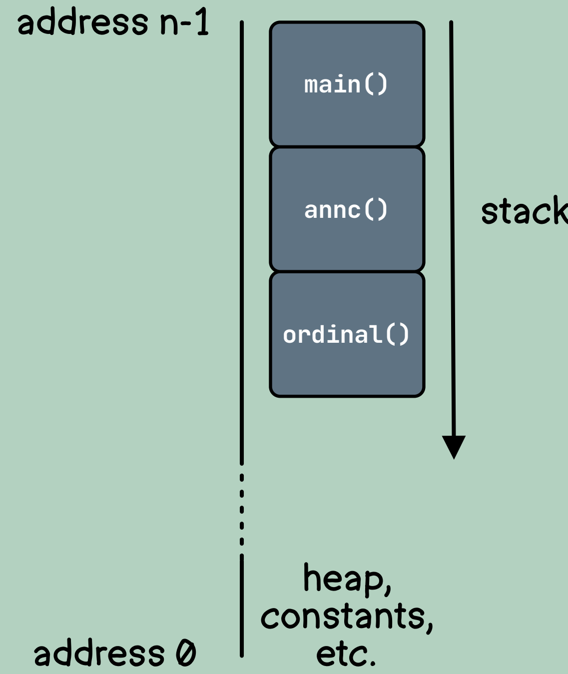



For what it's worth, the **`println()`** function itself technically calls *other* functions, so if we were to fully chart out all of those calls, the mountain range would look even more complex than it does above!

One last thing to note before we move on—in Listing 17.3, we've only got *functions* calling other *functions*, but a call stack will often include other things. For example, when we call a class' constructor, the properties of that class will also be initialized, and when that happens, it's also part of the call stack. Similarly, we might get a value from a *property* that has a custom getter function. These would also have their own frames on the stack.

## By the Way: Top and Bottom of the Stack

The *call stack* isn't a just a mental construct—each stack frame takes up actual space in the memory on your computer. Each slot of memory has an address, starting at zero and increasing up to the amount of memory allocated to your program. Interestingly, in most computer systems, the call stack actually starts at the *highest* memory address—that is, the slot whose address is the biggest number. Then, when a frame is added to the stack, it gets an address just *below* the previous frame's address.




On the other hand, in regular life, when you and I think about a stack—whether it's a stack of pancakes, dishes, or chairs—we put the newest item on the top of the stack, so the stack grows upward. However, because of the way a call stack takes up space in memory, starting at the highest memory address, developers usually consider it to grow downward—i.e., toward memory address zero.

This can lead to quite a bit of confusion. So when a programmer says that something's at the *top* of the call stack, sometimes they really mean that it's at the *first* frame in the stack (i.e., the **`main()`** function in Kotlin). Other times, though, a developer who says "top of the stack" might mean the *last* frame, as found in some of Java's documentation.

So now that we know all about the call stack, what does this have to do with exceptions and error messages?

## Call Stacks, Exceptions, and Error Messages

Let's update the **`main()`** function. Instead of passing the number **`1`** to **`annc()`**, let's pass it the number **`9`**, which will be out of bounds for the **`ordinal()`** function.

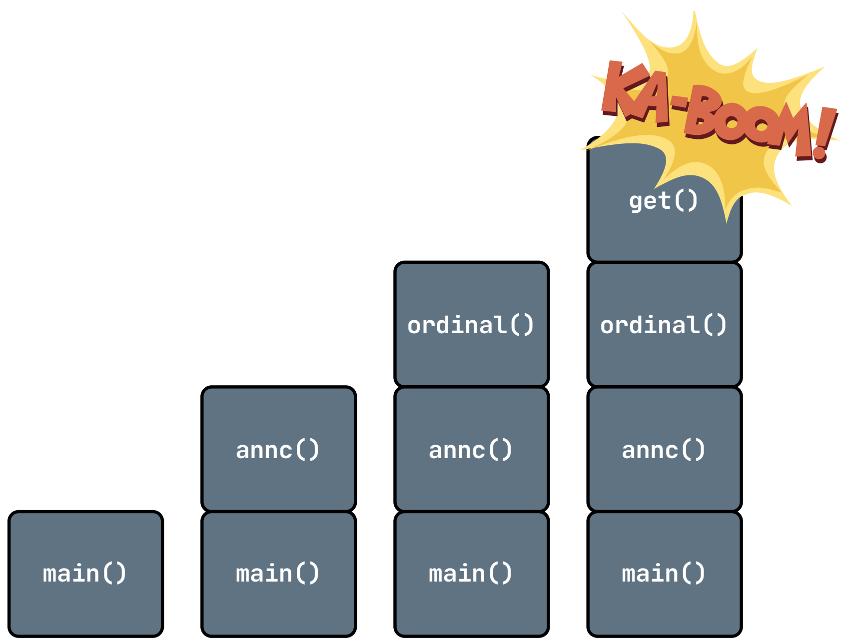
```
fun main() {
    val task = annc(9, "clean my room")
    println(task)
}
```

*Listing 17.5 - Triggering an exception with an out-of-bounds index.*

When this runs, instead of seeing "The ninth thing I will do is clean my room", we get an **`ArrayIndexOutOfBoundsException`**, just like we did back in Listing 17.2. Here's that error message again.

```
Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException: Index 9 out of
bounds for length 6
    at java.base/java.util.Arrays$ArrayList.get(Arrays.java:4165)
    at MainKt.ordinal(Main.kt:3)
    at MainKt.main(Main.kt:7)
    at MainKt.main(Main.kt)
```

Let's examine how the call stack changes over time as this code is running. When things blow up, the call stack has *four frames* on it.




The error message includes a snapshot of what the call stack looked like at the time that the exception happened. A snapshot of the call stack at the moment when an error occurred is known as a **stack trace**.

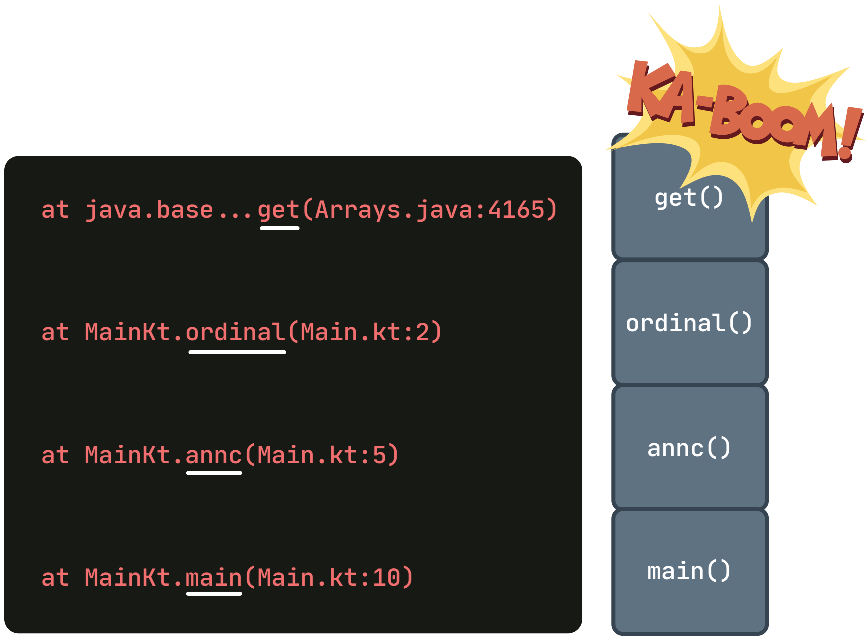
This exception...

```
Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException:
Index 9 out of bounds for length 6
    at java.base/java.util.Arrays$ArrayList.get(Arrays.java:4165)
    at MainKt.ordinal(Main.kt:2)
    at MainKt.annc(Main.kt:5)
    at MainKt.main(Main.kt:10)
    at MainKt.main(Main.kt)
```

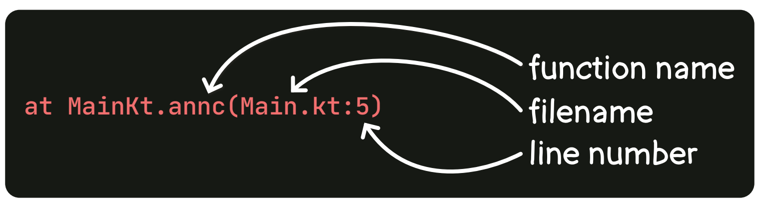
stack trace

... happened in this function

Note that, not counting the bottom line of the stack trace, it shows the same thing as our stack of boxes above.




For each frame in the stack trace, we can see the *name of the function*, the *name of the file* where that function is, and the *line number* of code where the next function was called.




It's easy to understand the stack trace, but let's take it one line at a time.

```
at java.base/java.util.Arrays$ArrayList.get(Arrays.java:4165)
```

This line tells us that the error happened in a function named **`get()`**, which is inside a class called **`ArrayList`**. This class belongs to Java's API, which was used by Kotlin's standard library, and the number at the end tells us that the error happened at line 4165. (Yes, that's a lot of lines!)

```
at MainKt.ordinal(Main.kt:2)
```

Next, we can see that the **`get()`** function (from the previous line) was called from our **`ordinal()`** function, at line 2 inside a file named **`Main.kt`**.

```
at MainKt.annc(Main.kt:5)
```

After that, **`ordinal()`** (from the previous line) was called by **`annc()`** on line 5 of **`Main.kt`**.

```
at MainKt.main(Main.kt:10)
```

And `annc()` was called by the `main()` function on line 10 of the same file.

```
at MainKt.main(Main.kt)
```

And this final line simply shows us that everything started in the `Main.kt` file.

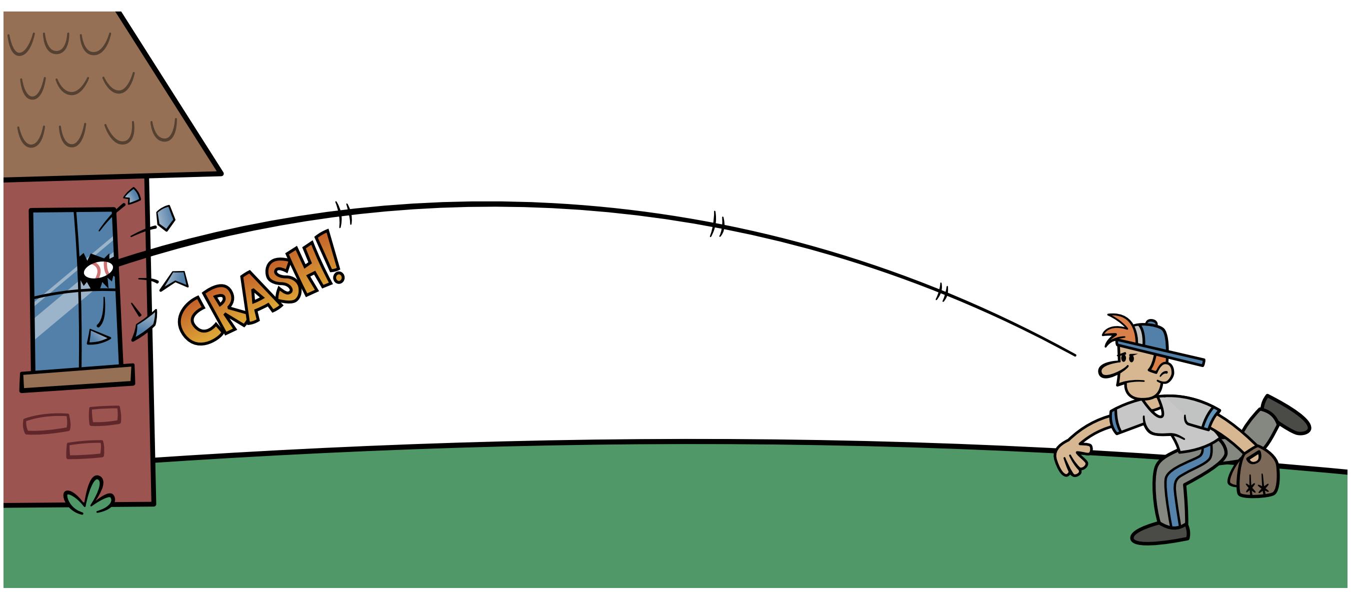
The stack trace can be helpful when we're trying to figure out what went wrong, but it also shows us where we could add code to try to *prevent* the program from abruptly terminating.

### Best Practice: Read the Error Messages

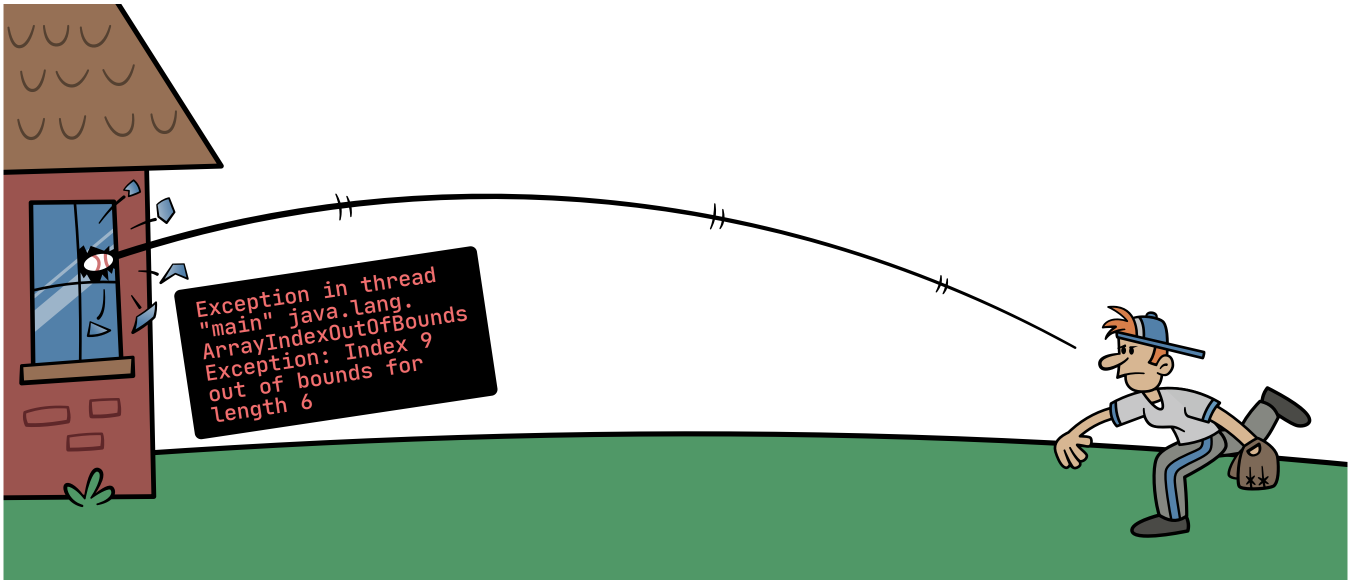
When we get an error message with a stack trace, it's tempting to jump right back into the code to try out a few things to determine what went wrong. I get it! But always take a moment to read the error message before moving on. Troubleshooting usually goes faster after you've taken the time to understand the full context.

## Catching Exceptions

When an exception arises, it's kind of like a kid throwing a baseball toward a window. If nobody is there to catch that baseball, it'll crash into the window.




Similarly, in our Kotlin code, when an exception is thrown, if nobody catches the exception, an error message will be printed out, and the program will crash.




Usually, we do *not* want our program to crash in response to an exception. To demonstrate why, let's replace our single task with a *list* of tasks, and print out an announcement for each one.

```
fun main() {
    val tasks = listOf(1 to "clean my room", 9 to "take out trash", 5 to "feed the dog")
    tasks.forEach { (number, task) ->
        println(annc(number, task))
    }
}
```

*Listing 17.6 - Printing out each announcement.*

When this runs, we'll see the following output.

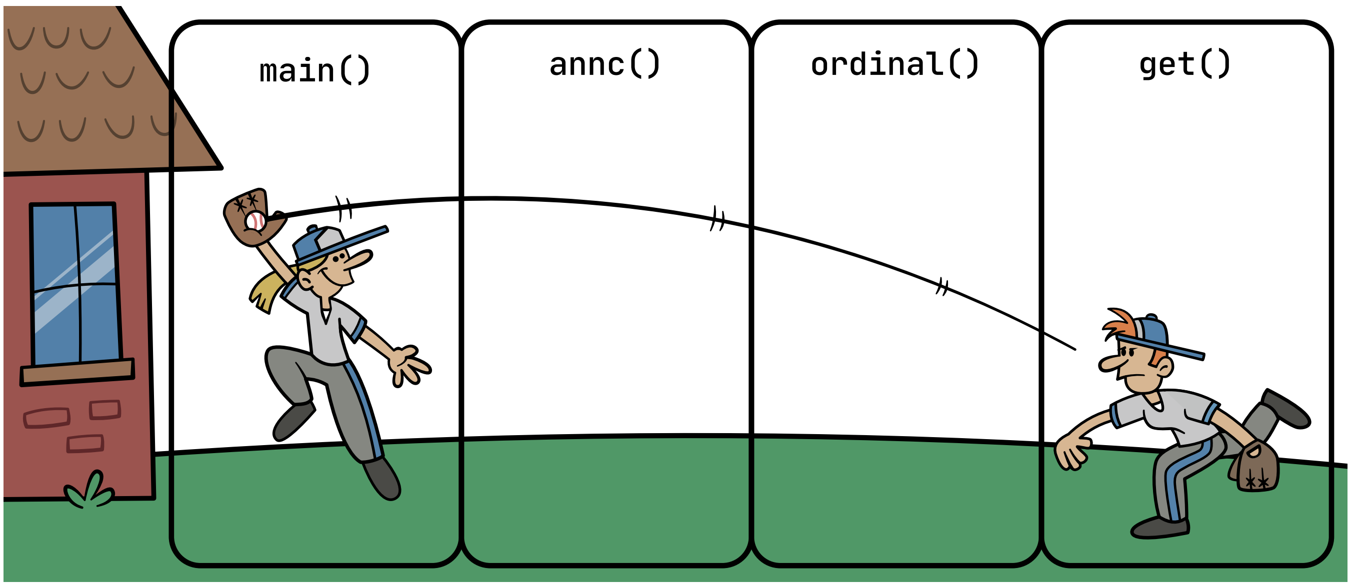
```
The first thing I will do is clean my room.
Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException: Index 9 out of bounds
for length 6
    at java.base/java.util.Arrays$ArrayList.get(Arrays.java:4165)
    at MainKt.ordinal(Main.kt:2)
    at MainKt.annc(Main.kt:5)
    at MainKt.main(Main.kt:11)
    at MainKt.main(Main.kt)
```

The first task was printed to the screen, but the second task caused an exception, so the program aborted. Because the program stopped running, it never printed out the task about feeding the dog!

Instead, it'd be great if the program would keep running, even when there's an exception. To keep the things running, we'll need to *catch* that exception. In other words, we need someone to catch that baseball before it crashes through the window!

So, how can we *catch* an exception? Well, we can put a baseball player at any frame of the call stack. Starting from the frame where it's thrown, the exception will pass by each stack frame, one by one, all the way through the `main()` function where the program started. At each step along the way, we can station a ball player who can catch the exception, preventing the window from breaking.

For example, we can put a catcher in the `main()` function, and she'll catch the exception just before it hits the window.




Let's add some code to catch an exception! To do this, we'll use a **try expression**, which looks like this.

```
try {
    // do something exception-prone here
} catch (exception: Exception) {
    // handle the exception here
}
```

"try" keyword

exception parameter

"catch" keyword

This expression has a few key parts:

1. It starts with the `try` keyword.
2. After that comes the `try` block. This is where we put the exception-prone code.
3. After that is the `catch` keyword.
4. Inside the parentheses is the **exception parameter**, which is declared with a name and the type of the exception that we want to catch. We'll learn more about this in a moment.
5. After that comes the `catch` block. This is where we put the code that should run when an exception is caught.

To start with, let's just put our catcher (that is, a *try expression*) in the **`main()`** function, where she can catch the exception just before it breaks the window. When we call **`annc()`**, an exception could end up getting thrown. Since that call is *exception-prone*, we'll put it *inside* the **`try`** block. Then, inside the **`catch`** block, we'll simply print out that something went wrong.

```
fun main() {
    val tasks = listOf(1 to "clean my room", 9 to "take out trash", 5 to "feed the dog")
    tasks.forEach { (number, task) ->
        try {
            println(annc(number, task))
        } catch (exception: Exception) {
            println("Something went wrong!")
        }
    }
}
```

*Listing 17.7 - Catching an exception and printing out that something went wrong.*

When we run this again, we'll still get an exception while processing **`"take out trash"`**, but this time, the exception will be *handled* by the **`catch`** block. As a result, we see this output.

```
The first thing I will do is clean my room.
Something went wrong!
The fifth thing I will do is feed the dog.
```

With this change, we prevented the program from crashing with an error message! That means we *still get to see the task about feeding the dog!* After processing all three tasks, the program ends successfully.

Printing out **`"Something went wrong!"`** is better than nothing, but there's much more we can do with exceptions when we catch them.

## Exceptions Are Objects

Exceptions are objects, and we can use their functions and properties, just like any other object.

```
try {
    println(announcement(number, task))
} catch (exception: Exception) {
    println("Something went wrong!")
}
```

In Listing 17.7 above, our catch block declared an *exception parameter* named **`exception`** and that parameter's type is **`Exception`**.

Although the variable name **`exception`** was used here, most developers prefer using very small variable names for exceptions, such as **`ex`** or just **`e`**.

```
try {
    println(annc(number, task))
} catch (e: Exception) {
    println("Something went wrong!")
}
```

*Listing 17.8 - Using a short variable name for an exception.*

This variable is visible inside the **`catch`** block, so we can interact with it as needed. For example, every **`Exception`** object has a nullable property named **`message`**, so let's update our **`println()`** to include that message.

```
try {
    println(annc(number, task))
} catch (e: Exception) {
    println("Something went wrong! ${e.message}")
}
```

*Listing 17.9 - Including the exception message in the output.*

*Now* when this runs, instead of just seeing that *something* went wrong, we can see *what it was* that went wrong—in this case, that index 9 was out of bounds for an array that has a length of 6.

```
The first thing I will do is clean my room.
Something went wrong! Index 9 out of bounds for length 6
The fifth thing I will do is feed the dog.
```

In addition to the **`message`** property, **`Exception`** objects include a stack trace, which we can print out with the **`printStackTrace()`** function.[1]

## By the Way: Looping Over the Stack Trace

You can even use collection operations to loop over and process the stack trace.

```
try {
    println(annc(number, task))
} catch (e: Exception) {
    e.stackTrace
        .reversed()
        .drop(1)
        .joinToString(" -> ") { "${it.methodName}()" }
        .let { println("Error: $it") }
}
```

[1] This function is available when your Kotlin code is targeting the Java Virtual Machine (JVM) or a native platform, but not currently available when targeting JavaScript.

The result is output that looks like this.

```
The first thing I will do is clean my room.
Error: main() -> annc() -> ordinal() -> get()
The third thing I will do is feed the dog.
```

Even though the `Exception` class is useful, we're not confined to using that class itself. We can extend it, and include any functions or properties that we want! Before that will be helpful, though, we'll first need to learn how to throw our own exceptions.

# Throwing Exceptions

In addition to *catching* exceptions, we can also *throw* them ourselves. Since an exception is just an object, we can instantiate one like usual—by calling its constructor. We don't *have* to pass any arguments to its constructor, but it can be helpful to give it a message describing the problem.

```kotlin
val exception = Exception("No cleaning allowed on holidays!")
```

*Listing 17.10 - Instantiating a new* `Exception`*.*

Once we have an instance of an exception, we can `throw` the exception with the throw keyword. Here's how that looks.

```kotlin
throw exception
```

*Listing 17.11 - Throwing the instantiated exception.*

However, the *stack trace* of an exception is determined at the point where the exception is *instantiated*, not the point at which it is *thrown*. For that reason, we don't usually instantiate and store an exception in a variable like we're doing in Listing 17.10. Instead, it's typical to instantiate an exception *when you throw it*, like this.

```kotlin
throw Exception("No cleaning allowed on holidays!")
```

*Listing 17.12 - Immediately throwing an instantiated exception.*

Let's update our `annc()` function so that if the `task` includes the word "clean", then we'll throw this exception.

```kotlin
fun annc(number: Int, task: String): String {
    if (task.contains("clean")) throw Exception("No cleaning allowed on holidays!")
    val ordinal = ordinal(number)
    return "The $ordinal thing I will do is $task."
}
```

*Listing 17.13 - Adding a* `throw` *to our* `annc()` *function.*

Running this with the try expression from Listing 17.9 results in this output.

```
Something went wrong! No cleaning allowed on holidays!
Something went wrong! Index 9 out of bounds for length 6
The fifth thing I will do is feed the dog.
```

Our try expression is now handling at least two different cases of exceptions:

1. An exception that is thrown when the task includes the word "clean".
2. An exception that is thrown when the index is out of bounds.

At the moment, we're handling both of those exceptions the same way, but we might prefer to handle each of those cases *differently*. To distinguish between these two different kinds of exceptions, we can make sure they have different types.

# Exception Types

Although we can instantiate the **`Exception`** class directly, as we did in Listing 17.13, it's often helpful to extend it for each unique category of exception that we throw. For example, we can create a subclass of **`Exception`** that's dedicated to holidays, when we aren't allowed to clean.

```kotlin
class HolidayException(val task: String) : Exception("'$task' is not allowed on holidays")
```

*Listing 17.14 - Creating a custom exception class.*

Now we can throw a **`HolidayException`** instead of a general **`Exception`**.

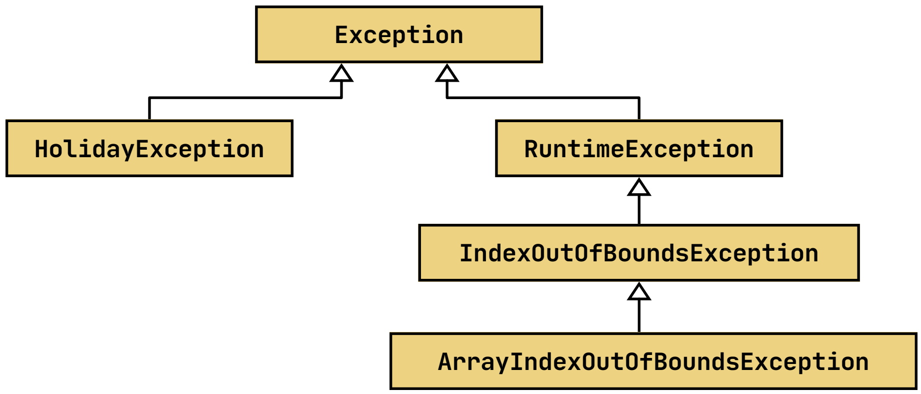
```kotlin
fun annc(number: Int, task: String): String {
    if (task.contains("clean")) throw HolidayException(task)
    // ...
}
```

*Listing 17.15 - Throwing an instance of our custom exception class.*

With this change, this program now deals with two kinds of exceptions:

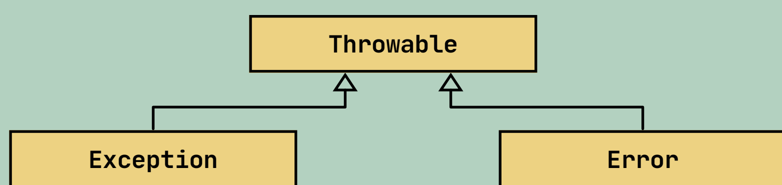
- **`ArrayIndexOutOfBoundsException`**, which could be thrown from the **`get()`** function of the list.
- **`HolidayException`**, which could be thrown from our **`annc()`** function.

Each of these is a subclass of the **`Exception`** class, although **`ArrayIndexOutOfBoundsException`** goes through a few intermediate classes. Here's a UML class diagram showing how these classes are related.




## By the Way: Throwables and Errors

**`Exception`** objects aren't the only things that can be thrown. In fact, **`Exception`** is a subclass of a class called **`Throwable`**. Any instance of **`Throwable`** or its subclasses can be used with the **`throw`** keyword. There's a second category of throwables that's a sibling to **`Exception`**, named **`Error`**.




Whereas **`Exception`** usually represents a deviation from the normal flow of code, an **`Error`** typically represents a more severe condition—one which we can't recover from, such as when the system runs out of memory. Although it's possible to catch these, there's usually not much you can do with them. So, you'll rarely need to catch anything other than exceptions.

Let's look at our try expression again.

```kotlin
try {
    println(annc(number, task))
} catch (e: Exception) {
    println("Something went wrong! ${e.message}")
}
```

*Listing 17.16 - Code from Listing 17.9.*

The *type* of the exception parameter tells Kotlin which *kinds* of exceptions should be handled in this catch block. This is like telling the ball players to only catch balls of a certain color, and ignore the others. In Listing 17.16, the type is **`Exception`**, so this catch block will handle any exceptions that have a type of **`Exception`**, *including any of its subtypes*. Because **`ArrayIndexOutOfBoundsException`** and **`HolidayException`** are both subtypes of **`Exception`**, this code will catch both of those exceptions. However, we can change this type to something more specific. For example, let's change it to **`HolidayException`**.

```kotlin
try {
    println(annc(number, task))
} catch (e: HolidayException) {
    println("Something went wrong! ${e.message}")
}
```

*Listing 17.17 - Catching a more specific exception type.*

With this change, we can run the code, and see that the try expression caught and handled the **`HolidayException`**, but it did *not* catch the **`ArrayIndexOutOfBoundsException`** caused by the second task.

```
Something went wrong! 'clean my room' is not allowed on holidays

Exception in thread "main" java.lang.ArrayIndexOutOfBoundsException:
Index 9 out of bounds for length 6

... (stack trace follows) ...
```

this exception was handled

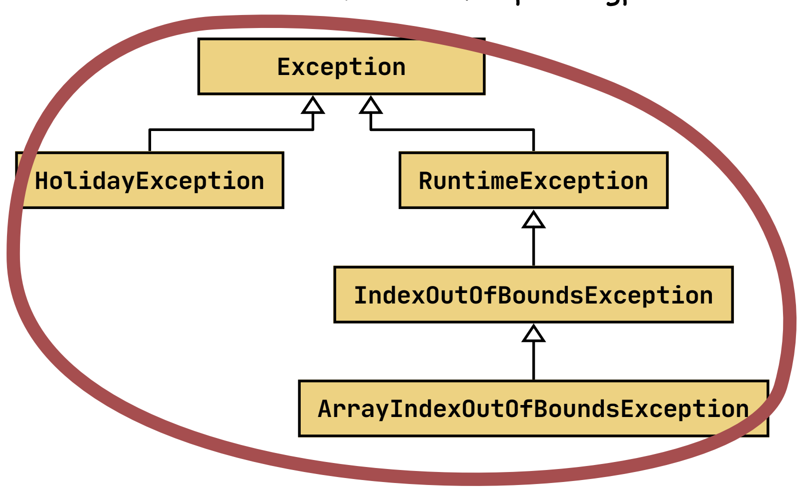
this exception was not handled

So, the *type* of the exception parameter determines which exceptions are caught. Just remember that the catch block will handle the specified type, *including* any of its subtypes.

This code...

```kotlin
try {
  // ...
} catch (e: Exception) {
  // ...
}
```

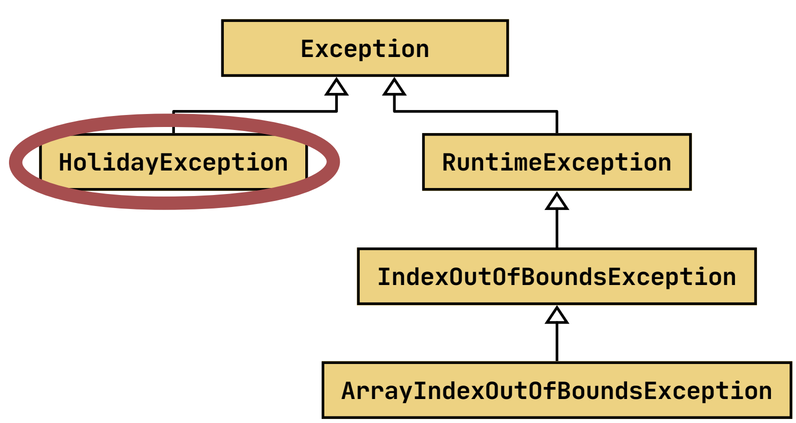
... will catch all of these exception types:




This code...

```kotlin
try {
  // ...
} catch (e: HolidayException) {
  // ...
}
```

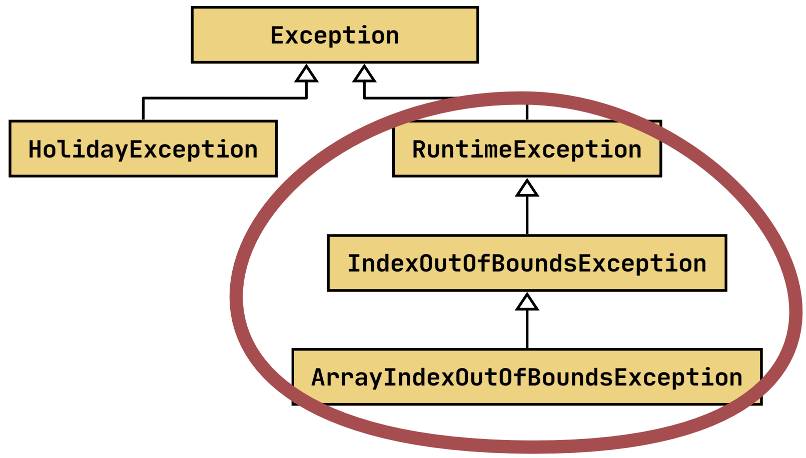
... will catch just this exception type:



This code...

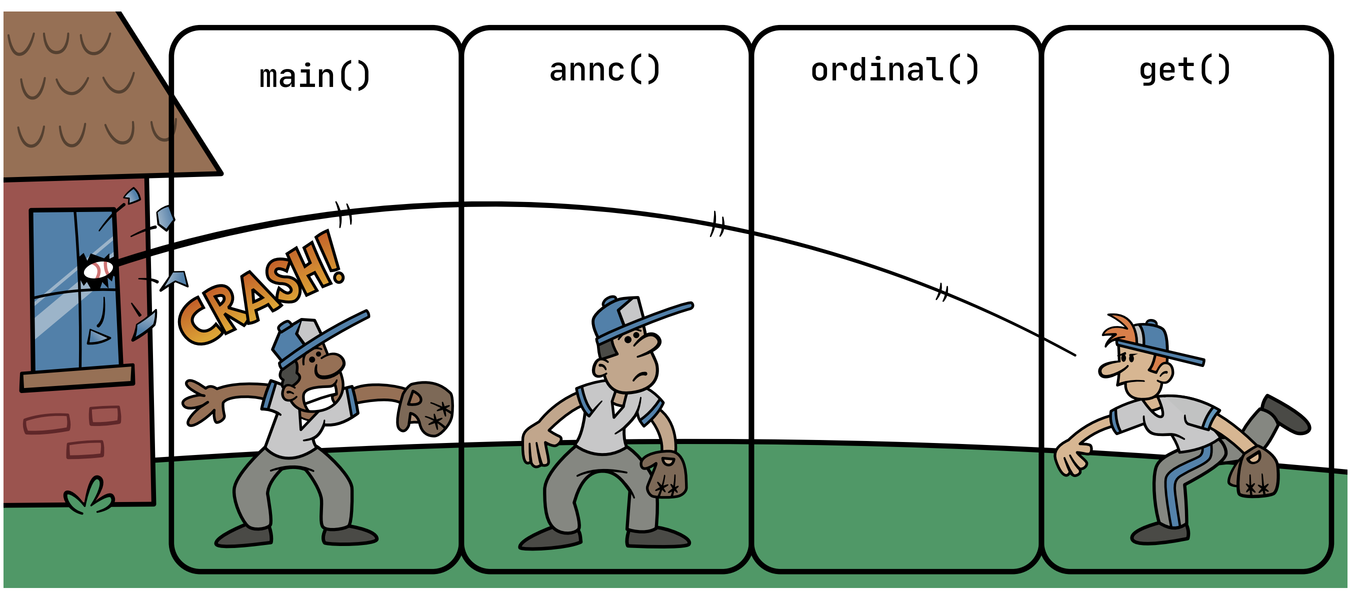
```kotlin
try {
  // ...
} catch (e: RuntimeException) {
  // ...
}
```

... will catch these exception types:




Any exception types that the catch block does *not* catch will simply continue to the next stack frame, where another try expression could have a chance to catch and handle it.

As always, if nobody catches the exception, it'll crash through the window.




## Handling Multiple Exception Types Differently

Sometimes we might want to handle multiple types of exceptions in a single try expression, but do something *different* with each one of them. For example, instead of catching a `HolidayException` and ignoring an `ArrayIndexOutOfBoundsException`, we might want the `main()` function to handle them both, but print out something different in each case.

To do this, we can simply append additional catch blocks as needed, like this.

```
try {
    println(annc(number, task))
} catch (e: HolidayException) {
    println("It's a holiday! I'm not going to ${e.task} today!")
} catch (e: ArrayIndexOutOfBoundsException) {
    println("I can't count that high!")
}
```

*Listing 17.18 - Multiple catch blocks for different exception types.*

```
It's a holiday! I'm not going to clean my room today!
I can't count that high!
The fifth thing I will do is feed the dog.
```

Note that when there's more than one catch block, the *first block with the matching exception type wins*—and any following blocks will be disregarded, even if the type of its exception parameter matches. Because of this, it's a good idea to think about the order of the catch blocks.

For example, we *could* add a catch block for **`Exception`** at the very top.

```
try {
    println(annc(number, task))
} catch (e: Exception) {
    println("I wasn't expecting this!")
} catch (e: HolidayException) {
    println("It's a holiday! I'm not going to ${e.task} today!")
} catch (e: ArrayIndexOutOfBoundsException) {
    println("I can't count that high!")
}
```

*Listing 17.19 - Catching a broad exception type at the top.*

However, if we do this, the two catch blocks that follow it will be pointless. Since **`HolidayException`** and **`ArrayIndexOutOfBoundsException`** are *subclasses* of **`Exception`**, they'll always only match the first block!

```
I wasn't expecting this!
I wasn't expecting this!
The fifth thing I will do is feed the dog.
```

So instead, if a single try expression is going to include cases for both an exception class *and* one or more of its *subclasses*, put the subclasses above their corresponding superclasses, as shown in Listing 17.20 below. In this code, a **`HolidayException`** will be handled in the first catch block, an **`ArrayIndexOutOfBoundsException`** will be handled in the second, and any other kind of exception will be handled in the third block.

```
try {
    println(annc(number, task))
} catch (e: HolidayException) {
    println("It's a holiday! I'm not going to ${e.task} today!")
} catch (e: ArrayIndexOutOfBoundsException) {
    println("I can't count that high!")
} catch (e: Exception) {
    println("I wasn't expecting this!")
}
```

*Listing 17.20 - Correct order for catch blocks.*

### Best Practice: Underscores

When a catch block doesn't actually need the exception parameter, use an underscore for its name.

```
catch (_: ArrayIndexOutOfBoundsException) {
    println("I can't count that high!")
}
```

So, with the right arrangement, it's possible to catch both specific and general exception types. Next, let's see how a try expression in Kotlin can be evaluated.

# Evaluating a Try Expression

Throughout this chapter, we've referred to try-catch as an *expression*. As you might recall, the difference between a statement and an expression is that an expression can be evaluated—in other words, it can be reduced to a value. Since try expressions are indeed expressions, we can assign them to variables, pass them to functions, or return them from functions. For example, currently, our try expression in the `main()` function is calling `println()` in each case.

```
try {
    println(annc(number, task))
} catch (e: HolidayException) {
    println("It's a holiday! I'm not going to ${e.task} today!")
} catch (e: ArrayIndexOutOfBoundsException) {
    println("I can't count that high!")
}
```

*Listing 17.21 - Calling `println()` in each block of the try expression.*

Instead of calling `println()` everywhere, we can simply let this try expression evaluate to a `String`. To do this, we just remove each `println()`, and assign the result to a variable. Then we can print that variable.

```kotlin
val words: String = try {
    annc(number, task)
} catch (e: HolidayException) {
    "It's a holiday! I'm not going to ${e.task} today!"
} catch (e: ArrayIndexOutOfBoundsException) {
    "I can't count that high!"
}

println(words)
```

*Listing 17.22 - Assigning the result of a try expression to a variable.*

This works exactly as you would expect.

- If there are no exceptions, the result of **`annc()`** will be assigned to the **`words`** variable.
- If there's a **`HolidayException`**, then the string in that block will be assigned to **`words`**. ("It's a holiday!…")
- If there's an **`ArrayIndexOutOfBoundsException`**, then "I can't count that high!" will be assigned to **`words`**.
- If there's any other exception, it won't be caught here. It'll continue working its way toward the start of the call stack.

# Try-Catch-Finally

Sarah takes pride in having a lush, green, well-manicured lawn. Twice a week, she would turn on the outdoor faucet to start watering her lawn.

One day, after turning on the faucet, she noticed that the sprinkler wasn't spinning like it should. Realizing that the sprinkler was broken, she went into the house and ordered a new one from an online store. Then, she continued with everything else that she needed to do that day.

Unfortunately, by the end of the day, her lawn was flooded, because she never turned off the faucet!

Just like Sarah, sometimes we need to make sure we wrap up a task, even if something goes wrong! The following code models her experience.

```kotlin
try {
    faucet.turnOn()
    watch(sprinkler) // SprinklerBrokenException is thrown here
    faucet.turnOff() // This never runs!
} catch (e: SprinklerBrokenException) {
    store.orderNewSprinkler()
}
```

*Listing 17.23 - If an exception is thrown in `watch()`, then `faucet.turnOff()` will never run.*

This code seems reasonable, but there's a problem with it—if the **`watch()`** function throws a **`SprinklerBrokenException`**, then **`faucet.turnOff()`** never runs!

To help with cases like this, we can include a block named **`finally`** at the end of a try expression. A *finally* block will run after the rest of the expression is processed, regardless of whether an exception was thrown. Here's how it looks.

```
try {
    faucet.turnOn()
    watch(sprinkler) // SprinklerBrokenException is thrown here
} catch (e: SprinklerBrokenException) {
    store.orderNewSprinkler()
} finally {
    faucet.turnOff() // This will run, even when the sprinkler breaks!
}
```

*Listing 17.24 - The* **`finally`** *block ensures that* **`faucet.turnOff()`** *will run.*

With this code:

- If no exception is thrown, then **`faucet.turnOff()`** will run after **`watch(sprinkler)`** completes.
- If a **`SprinklerBrokenException`** is thrown, then **`faucet.turnOff()`** will run after **`store.orderNewSprinkler()`** runs.
- If any other kind of exception is thrown, then **`faucet.turnOff()`** will run before the exception makes its way toward the start of the stack.

A **`finally`** block is typically most helpful with resources that need to be closed. For example, if our program reads a file on the computer's hard drive, we'll want to make sure that we close it when we're done with it, even if an exception is thrown while processing it.

## By the Way: Closeable Resources

When your Kotlin code targets the JVM, you might use a resource that implements the **`Closeable`** interface, such as a **`FileReader`**.

When doing this, rather than using try-finally directly, you can use an extension function named **`use()`**. It will automatically close the resource, regardless of whether an exception is thrown.

```
FileReader(file).use { reader ->
    // Use the FileReader here
}
```

Note that it's possible to use **`finally`** with **`try`**, even when we don't have any **`catch`** blocks! For example, we might want the exception to be handled by *another* try-expression closer to the start of the stack, but still need to make sure we turn the faucet off.

```
try {
    faucet.turnOn()
    watch(sprinkler)
} finally {
    faucet.turnOff()
}
```

*Listing 17.25 - Using **`finally`** without **`catch`**, for guaranteed execution.*

At minimum, a try expression must have a catch block or a finally block.

Try expressions are a bit verbose. They tend to take up a lot of space on the screen, and they result in an execution path that can be difficult to follow, because it's not always obvious *where* an exception will be handled. Kotlin includes another approach to exception handling, which is also worth considering.

# A Functional Approach to Exception Handling

Kotlin's standard library includes a function named **`runCatching()`**. Internally, it uses a try expression, but by using this function, we can often avoid manually writing a try expression in our own code. Using this function is easy. To start with, simply call it with the exception-prone code, and assign its result to a variable, like this.

```
fun main() {
    val tasks = listOf(1 to "clean my room", 9 to "take out trash", 5 to "feed the dog")
    tasks.forEach { (number, task) ->
        val result = runCatching { annc(number, task) }
    }
}
```

*Listing 17.26 - Using **`runCatching()`** instead of using a try expression directly.*

**`runCatching()`** will return a **`Result`** object, which will contain one of two things—either a successful result, or an exception. In the code above, this means:

1. If **`annc()`** completes successfully, then it will contain the result that **`annc()`** returned.

2. If **`annc()`** throws an exception, then it will contain that exception.

The **`Result`** object has a few functions on it that can be used to work with the result or exception. An easy way to work with it is to use its **`getOrDefault()`** function. For example, the following code does the same thing as Listing 17.8.

```
val result = runCatching { annc(number, task) }
val text = result.getOrDefault("Something went wrong!")
println(text)
```

*Listing 17.27 - Using* `getOrDefault()` *for default values.*

In this code, if `annc()` completes successfully, then its result will be assigned to the `text` variable. Otherwise the string `"Something went wrong!"` will be assigned to it. This works just fine in many cases, but if we need the default to be based on a property of the *exception*—for example, if we want to include the `message` of the exception—then we'll need something else.

For cases like these, we can use `getOrElse()`. This function takes a lambda where you can operate on the exception object.[1] For example, the code below works the same as Listing 17.9.

```
val result = runCatching { annc(number, task) }
val text = result.getOrElse { "Something went wrong! ${it.message}" }
println(text)
```

*Listing 17.28 - Using* `getOrElse()` *so that we can reference the exception.*

The `Result` class includes a number of other functions that can be used to transform its value or exception. These functions can be chained together, much like a collection operation chain.

`runCatching()` and `Result` can make some code easier to read than their equivalent try expressions. However, if we write the try expression ourselves, we get more control—we can catch specific kinds of exceptions, and we can add a `finally` block if it's needed.

Also, developers who come from a Functional Programming background often want more advanced functionality than the `Result` class provides, such as the ability to catch only certain kinds of exceptions, or the ability to accumulate multiple exceptions. If that's you, you'll probably want to check out the Arrow libraries for Kotlin.

# Summary

You've done an *exceptional* job learning all about exceptions in this chapter! And now, when a curveball comes your way at runtime, you'll be ready to catch it. Here's what you learned in this chapter:

- Why we can end up with problems at runtime.
- What a call stack is, and how to read a stack trace.

[1] The type of this object isn't actually `Exception`; it's `Throwable`. See the *Throwables and Errors* aside above for more information about how they relate to one another.

- How to catch an exception, and what you can do with it once you've got one.
- How to throw your own exceptions.
- How to catch different types of exceptions.
- How try-catch is an expression, so it can be assigned to variables.
- How to use a finally block to make sure something happens, regardless of success or failure.
- How to use **`runCatching()`** for a more functional approach to exception handling.

Next, let's step up to the plate to take a swing at generic types!

Kotlin: An Illustrated Guide

Chapter 18

# Generics

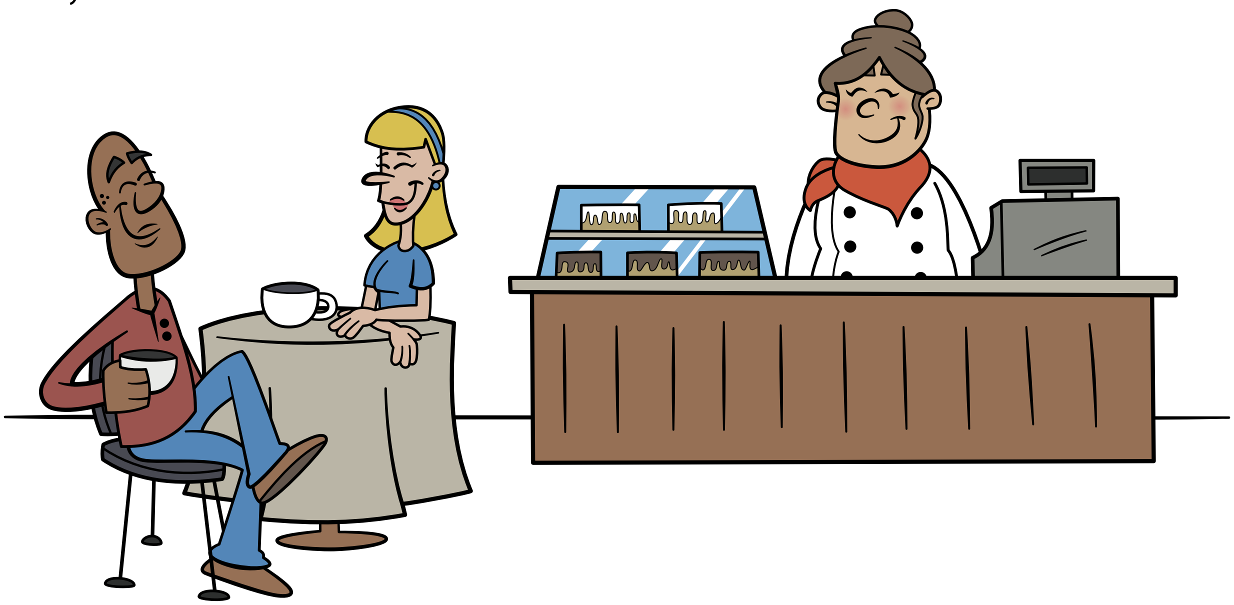
# If parameters are so helpful for functions, imagine what they can do for types!

All the way back in Chapter 8, when we introduced collections, we saw our first generic type: `List<String>` ... then we saw more generics in Chapter 9 when we looked at the `Pair` and `Map` classes. In order to stay focused on learning about collection types, we glossed over the details about these classes.

Well, we've put off learning about them for long enough! It's finally time for us to gain a full understanding of generics, so buckle up!

# Mugs and Beverages

Jennifer's bakery café offers delightful, sweet pastries and hot beverages, which you can enjoy at a dainty table or in a cozy chair.



As Jennifer's business has been picking up lately, she reached out to her brother Eric, who has been learning Kotlin, to model her operations for her. Eric decided to start with the beverage menu, which includes light, medium, and dark roast coffees, served in a ceramic mug. He decided to use an enum class to represent the coffee options, and a simple class to represent the mug. He also added a **`drink()`** function, which prints a line whenever a customer drinks the coffee.

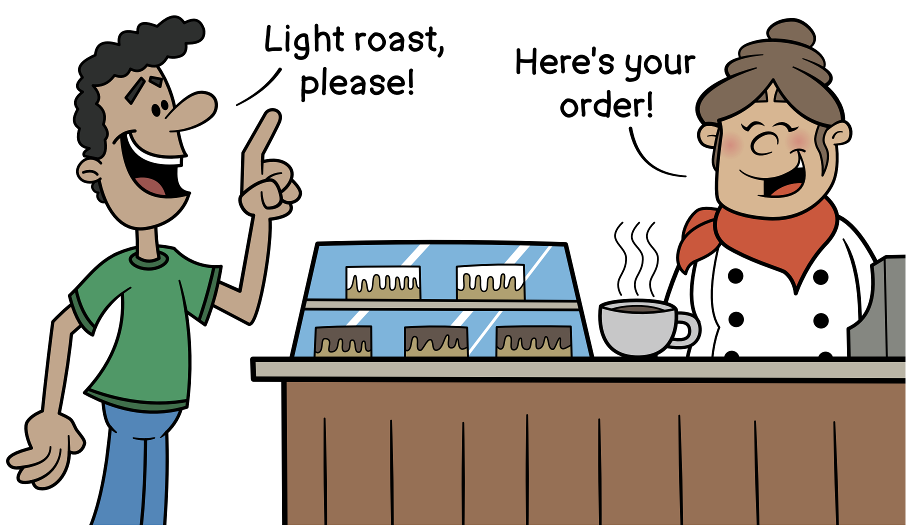
```
enum class Coffee { LIGHT_ROAST, MEDIUM_ROAST, DARK_ROAST }
class Mug(val beverage: Coffee)

fun drink(coffee: Coffee) = println("Drinking coffee: $coffee")
```

*Listing 18.1 - Modeling the coffee and mugs.*

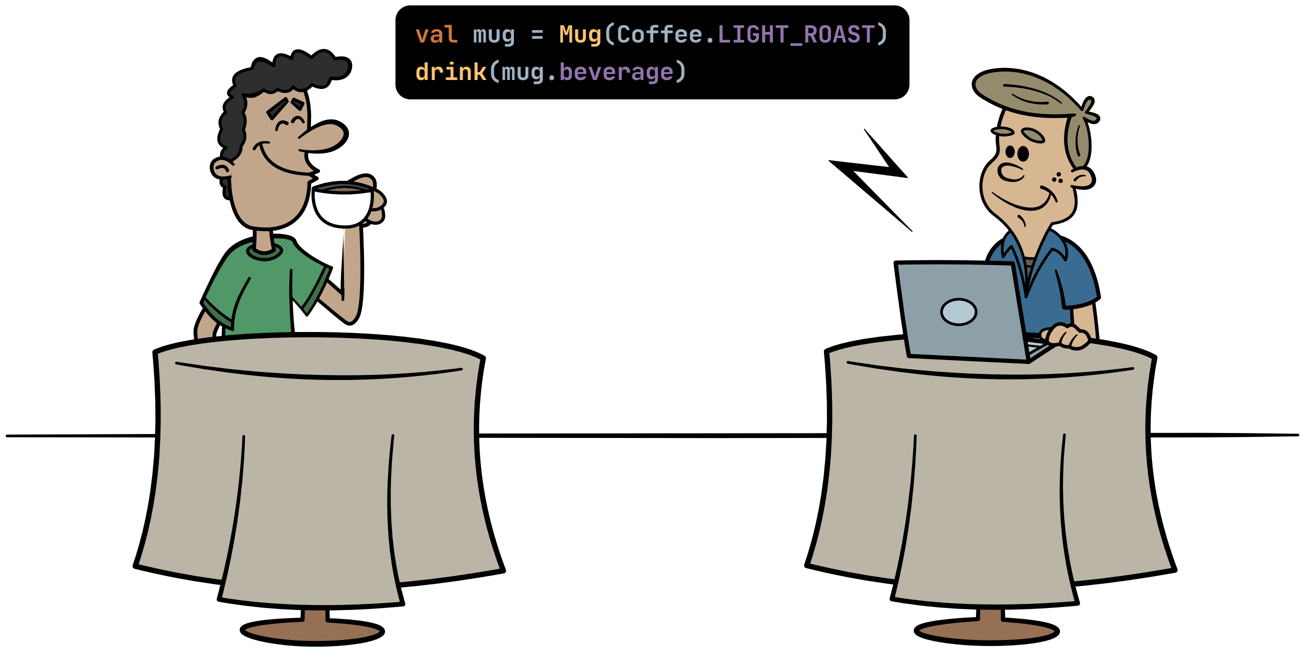
Now, whenever a customer orders a coffee, Eric can just instantiate a Mug with the right kind of coffee.

```
val mug =
    Mug(Coffee.LIGHT_ROAST)
```

*Listing 18.2 - Instantiating a Mug with the right kind of coffee.*



And when he takes a sip of his coffee, Eric can call the **`drink()`** function, passing the beverage in the mug as an argument.




```
drink(mug.beverage) // Drinking coffee: LIGHT_ROAST
```

*Listing 18.3 - Calling the* **`drink()`** *function with the beverage that's in the mug.*

One day, Jennifer decided that it was time to expand her beverage menu to include hot tea. As with the coffee, Eric chose to model these new tea options as an enum class. He also created an overload of the **`drink()`** function that accepts tea.

```
enum class Tea { GREEN_TEA, BLACK_TEA, RED_TEA }
fun drink(tea: Tea) = println("Drinking tea: $tea")
```

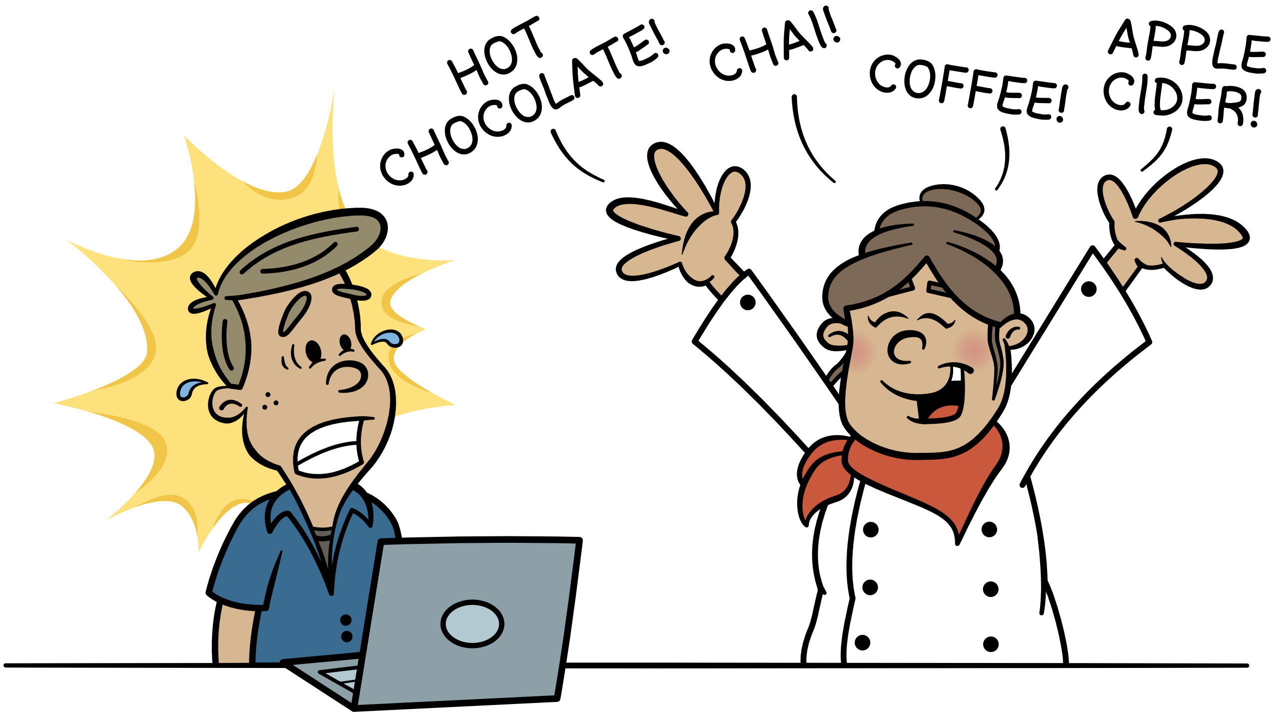
*Listing 18.4 - A new enum class representing tea, plus an overload of the* **`drink()`** *function.*

The **`Mug`** class also needed some work. After all, it's not possible to pass an instance of **`Tea`** to a **`Mug`** that accepts only **`Coffee`**! Eric thought about it. "Well, I guess I can just create another mug class, just for tea." So he renamed **`Mug`** to **`CoffeeMug`**, and added another class, named **`TeaMug`**.

```
class CoffeeMug(val coffee: Coffee)
class TeaMug(val tea: Tea)
```

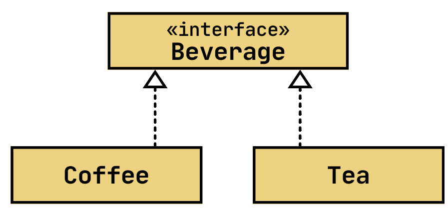
*Listing 18.5 - Renaming* **`Mug`** *to* **`CoffeeMug`***, and introducing a new* **`TeaMug`** *class.*

As he finished typing, Jennifer walked up to him and said, "Have I mentioned that I'm going to be expanding my beverage menu next week? I'll be adding *hot chocolate*, *apple cider*, and more!"




Eric grimaced. "The more *beverages* my sister adds to the menu, the more *mug classes* I'll have to create. This could get out of hand quickly. How can I make a single **`Mug`** class that can hold *any* kind of beverage?"

So he thought about how a subtype can be used anywhere that the compiler expects a supertype. "That's it!" he exclaimed. "I'll create an interface for the general concept of a beverage, and update the tea and coffee classes so that they're subtypes!"




He also updated the **`Mug`** class so that its property's type is **`Beverage`**. Here's what he ended up with.

```
interface Beverage
enum class Tea : Beverage { GREEN_TEA, BLACK_TEA, RED_TEA }
enum class Coffee : Beverage { LIGHT_ROAST, MEDIUM_ROAST, DARK_ROAST }

class Mug(val beverage: Beverage)
```

*Listing 18.6 - Creating a sealed interface for a beverage type.*

After making this change, he was able to create instances of **`Mug`** with *either* **`Coffee`** or **`Tea`**.

```
val mugOfCoffee = Mug(Coffee.LIGHT_ROAST)
val mugOfTea = Mug(Tea.BLACK_TEA)
```

*Listing 18.7 - Instantiating a mug of coffee and a mug of tea.*

"Huzzah! I've got a single mug class that can hold *any* kind of beverage!" When he ran his Kotlin code, though, he was alarmed to see some compiler errors—the call to the **`drink()`** functions no longer worked!

```
fun drink(coffee: Coffee) = println("Drinking coffee: $coffee")
fun drink(tea: Tea) = println("Drinking tea: $tea")

drink(mugOfCoffee.beverage)
drink(mugOfTea.beverage)
```

*Listing 18.8 - **Error:** None of the functions can be called with the arguments supplied...*

Why isn't this working? Let's take a closer look.

# Declared Types, Actual Types, and Assignment Compatibility

As we learned back in Chapter 12, objects have more than one type at a time. For example, a **`Coffee`** object has a type of **`Coffee`**, but it also has a type of **`Beverage`** *and* **`Any`**. This means it can be assigned to a variable that is declared with any of those types.

```
val coffee:   Coffee   = Coffee.MEDIUM_ROAST
val beverage: Beverage = Coffee.MEDIUM_ROAST
val anything: Any      = Coffee.MEDIUM_ROAST
```

*Listing 18.9 - Assigning **`Coffee.MEDIUM_ROAST`** to variables that have different types.*

As a result, there can be a difference between the type of the *variable* and the type of the *object inside that variable*. This brings up a few important terms.

- The type that a variable has been declared with is known as its **declared type**.
- The most specific type of the object *inside* a variable is known as its **actual type** or its **runtime type**.

```
val coffee:   Coffee   = Coffee.MEDIUM_ROAST
val beverage: Beverage = Coffee.MEDIUM_ROAST
val anything: Any      = Coffee.MEDIUM_ROAST
```

Declared Types

Actual Type is Coffee in each case

When we assign an object to a variable, property, or parameter, the *actual* or *runtime type* is irrelevant. Only the *declared type* matters. For example, in the following code listing, the second line fails.

```
val beverage: Beverage = Coffee.MEDIUM_ROAST
val coffee: Coffee = beverage
```

*Listing 18.10 - **Error:** Type mismatch. Required: Coffee. Found: Beverage.*

Even though you and I know the *actual type* of the object inside the **`beverage`** variable at runtime will definitely be **`Coffee`**, its *declared type* is **`Beverage`**. And since a variable whose type is **`Beverage`** could *possibly* hold objects other than **`Coffee`**—it could hold a **`Tea`** object, for example—Kotlin won't let us perform this assignment.

In order for an assignment to succeed, the type of an expression on the right-hand side of the equal sign must be the same as the declared type on the left-hand side, or one of its subtypes.

The type of this expression...

```
val beverage: Beverage = Coffee.MEDIUM_ROAST
```

...must be Beverage or one of its subtypes.

**Assignment compatibility** is the term we use to describe whether the object on the right-hand side can be assigned to the variable's type on the left-hand side. When it *can* be assigned, we say that the object is **assignment-compatible** with that type.

Even though we've been talking specifically about literal assignments involving an equal sign, it's important to note that when we call a function with an argument, we're effectively assigning an object to the function's parameter, so all of the same rules apply.

The type of this expression...

```
drink(Coffee.MEDIUM_ROAST)
```

...must be Coffee or one of its subtypes.

```
fun drink(coffee: Coffee) =
    println("Drinking coffee: $coffee")
```

Let's look at the relevant parts of Eric's code again.

```
fun drink(coffee: Coffee) = println("Drinking coffee: $coffee")
fun drink(tea: Tea) = println("Drinking tea: $tea")

class Mug(val beverage: Beverage)

val mugOfCoffee = Mug(Coffee.LIGHT_ROAST)
drink(mugOfCoffee.beverage)
```

*Listing 18.11 - **Error:** None of the following functions can be called with the arguments supplied.*

Regardless of the **`beverage`** property's *actual type* at runtime (e.g., **`Coffee`** in this example), it can be assigned neither to a parameter of type **`Coffee`**, nor to a parameter of type **`Tea`**, because its *declared type* is **`Beverage`**. In other words, **`beverage`** is not assignment-compatible with either of the **`drink()`** overloads. This is why Eric's code is failing.

For this to compile without errors, he would need to cast the **`beverage`** property back to the **`Coffee`** type to make it assignment-compatible with one of the **`drink()`** overloads.

```
val mugOfCoffee = Mug(Coffee.LIGHT_ROAST)
drink(mugOfCoffee.beverage as Coffee)
```

*Listing 18.12 - Casting the* `Beverage` *to* `Coffee` *before calling* `drink()`.

Although this works, this means that *every time* Eric gets the **`beverage`** property off of a **`Mug`**, if he needs to assign it to the more specific **`Coffee`** or **`Tea`** type, he would need to cast it. Every time!

It'd be great if he could have a single **`Mug`** class that could work with any kind of **`Beverage`**, *and* avoid the need to cast the **`beverage`** property all the time. Thankfully, this can be solved with **generic** types!

# Introduction to Generic Types

## Declaring a Generic Type

For a long time now, we've utilized functions to reuse expressions. By calling them with different arguments, we get different results. For example, we created this function to figure out the circumference of a circle back in Listing 2.3.

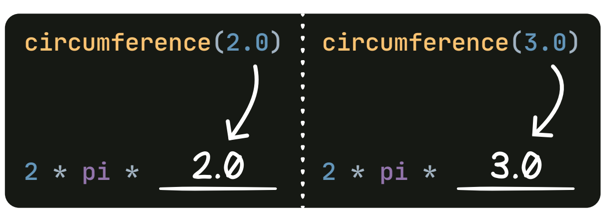
```
fun circumference(radius: Double) = 2 * pi * radius
```

*Listing 18.13 - From Listing 2.3 in Chapter 2.*

A function with a parameter like this is kind of like a fill-in-the-blank expression.

```
2 * pi * ______
```

Whenever we call it, we give it an argument to put into that blank.

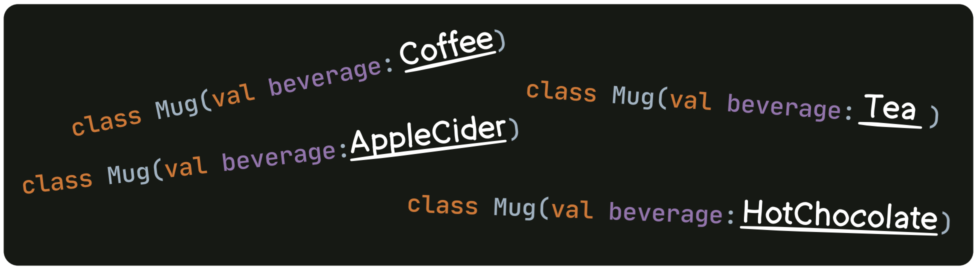



So a function's parameter is basically a blank that we can fill in with a *value*.

What if there were something similar for *types*? For example, what if the type of the **`beverage`** property were a blank that we could fill in with different types?

```
class Mug(val beverage:______)
```

Imagine all the different types we could put there!




Well, just like *functions* can have *parameters*, *types* can have **type parameters**. To add a *type parameter* to a class, put the name of the type parameter inside angle brackets **<** and **>**, to the right of the name of the class.


Here, we named the type parameter `BEVERAGE_TYPE`, but it's more typical to give them names that are just one letter long, such as `T` for "type".

```
class Mug<T>(val beverage: T)
```

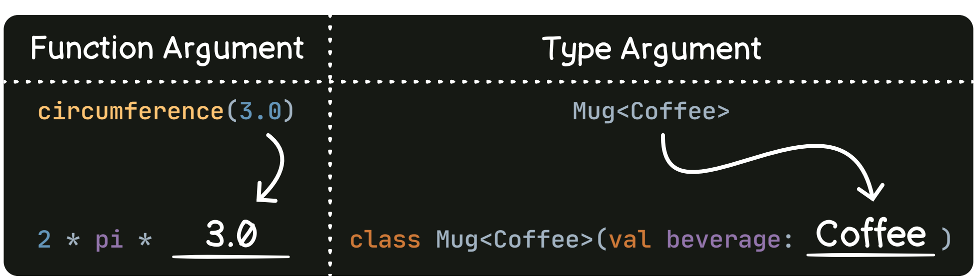
*Listing 18.14 - A type parameter whose name is only one letter long.*

With this code, the `Mug` class can now be used with different types! Let's see how to do that next.

## Using a Generic Type

When we call a function that has a parameter, we have to supply an *argument* for that parameter. Likewise, when creating an instance of a `Mug`, we'll have to supply a **type argument** for the type parameter named `T`. To do this, we can put the type argument in angle brackets next to the name of the class, as shown to the right.

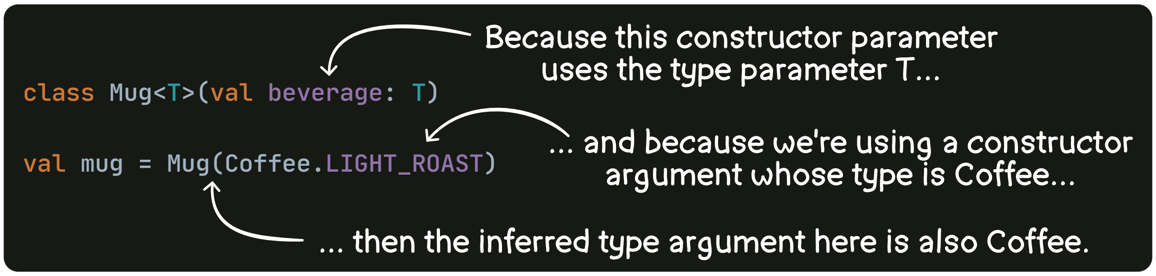

Much like calling a function with an argument is effectively the same as replacing the parameter with that value, creating a type with a type argument is effectively like filling in the type parameter with that type.[1]




[1] Note that the right side of the illustration shows what the "effective" class would be. In other words, by creating a `Mug<Coffee>` type, it's as if we had declared another class named `Mug<Coffee>` whose `beverage` type is `Coffee`. However, we don't actually *write* that code—by creating the generic class in Listing 18.14, Kotlin has all it needs to create the type for us!

Even though a type argument must be supplied when constructing a generic class, we usually don't have to write it out ourselves, because Kotlin can use its type inference to figure it out.

For example, since the constructor of **`Mug`** takes an argument whose type is **`T`**, Kotlin knows that if you create an instance with **`Mug`** and pass it a **`Coffee`** object, then the type argument for this **`Mug`** instance should be **`Coffee`**.



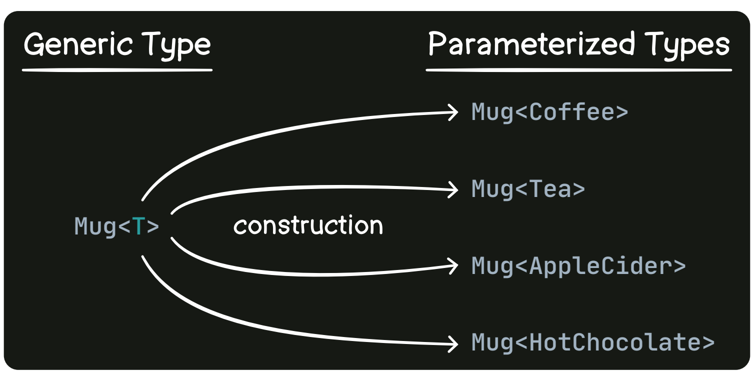

Note that the type of this **`mug`** variable is *not* **`Mug<T>`**. It's **`Mug<Coffee>`**. We can explicitly specify its type like this.

```
val mug: Mug<Coffee> = Mug(Coffee.LIGHT_ROAST)
```

*Listing 18.15 - Explicitly specifying the type of the mug variable.*

It's important to be able to distinguish between **`Mug<T>`** and **`Mug<Coffee>`**.

- A class that has a *type parameter*, such as **`Mug<T>`**, is known as a **generic type**.
- A generic whose type parameter has been filled with a type argument is known as a **parameterized type**.




The great thing about making the **`Mug`** class generic is that the **`beverage`** property will *retain its specific type*.

- When getting the **`beverage`** property from a **`Mug<Coffee>`**, its type will be **`Coffee`**.
- When getting the **`beverage`** property from a **`Mug<Tea>`**, its type will be **`Tea`**.

Because of this, there's no need to cast it when using it with code that expects a specific type!

For example, in the following code, we don't need to cast the **`beverage`** property to **`Tea`**, because that's what its type is already. So, the call to **`drink(tea: Tea)`** works just fine.

```
val mug: Mug<Tea> = Mug(Tea.GREEN_TEA)
drink(mug.beverage)
```

*Listing 18.16 - The type of* `mug.beverage` *here is* `Tea`*, so there is no need to cast it.*

After Eric made all of these changes, the customers were able to enjoy their tea and coffee. He was able to use a single **`Mug`** class, and never needed to cast the **`beverage`** property.

He was about to discover some surprises with his code, though! Let's find out what happened next.

# Type Parameter Constraints

One day, Jennifer decided to replace all of the café's ceramic mugs with fancy new temperature-controlled mugs that will keep the customers' tea and coffee at just the right drinking temperature.

She looked at Eric and said, "The mug will need to set its temperature based on the beverage inside it. If there's tea in the mug, then it should set the temperature to 60 degrees Celsius. If there's coffee in there, then it should set it to only 57 degrees."

Eric rolled up his sleeves and got to work. He updated all of the **`Beverage`** types, so that coffee and tea can each have its own ideal temperature.

```
sealed interface Beverage {
    val idealTemperature: Int
}

enum class Tea : Beverage {
    GREEN_TEA, BLACK_TEA, RED_TEA;
    override val idealTemperature = 60
}

enum class Coffee : Beverage {
    LIGHT_ROAST, MEDIUM_ROAST, DARK_ROAST;
    override val idealTemperature = 57
}
```

*Listing 18.17 - Adding an* `idealTemperature` *property to each beverage type.*

Next, in order to represent the temperature-controlled mug, he added a new **`temperature`** property to his **`Mug`** class, and assigned it to the beverage's ideal temperature. To his surprise, he ended up with an error!

```
class Mug<T>(val beverage: T) {
    val temperature = beverage.idealTemperature
}
```

*Listing 18.18 - **Error:** Unresolved reference:* `idealTemperature`*.*

It seems that the **`Mug`** class is unable to see the new **`idealTemperature`** property that he added. As Eric wondered about this, a customer walked up to Jennifer and asked why his mug had a string in it!

"A string? It's supposed to be a beverage!" Jennifer cried. She shot a glance to her brother, who looked at the customer. It was true, there was a string in his mug!

Eric looked back down at his computer screen and hammered out some more code.

Sure enough, it was possible to put a **`String`** in a **`Mug`**. In fact, as the **`Mug`** code is currently written, literally *anything* can be stuffed inside it!

```
val mugOfString: Mug<String> = Mug("How did this get in the mug?")
val mugOfInt: Mug<Int> = Mug(5)
val mugOfBoolean: Mug<Boolean> = Mug(true)
val mugOfEmptiness: Mug<Any?> = Mug(null)
```

*Listing 18.19 - Stuffing a* **`String`***, an* **`Int`***, a* **`Boolean`***, and a null into a mug.*

So Eric now had two problems:

1. The **`Mug`** class can't see the **`idealTemperature`** property of its **`Beverage`** (Listing 18.18).
2. The **`Mug`** class can hold an object of any type, but it should only hold a **`Beverage`** (Listing 18.19).

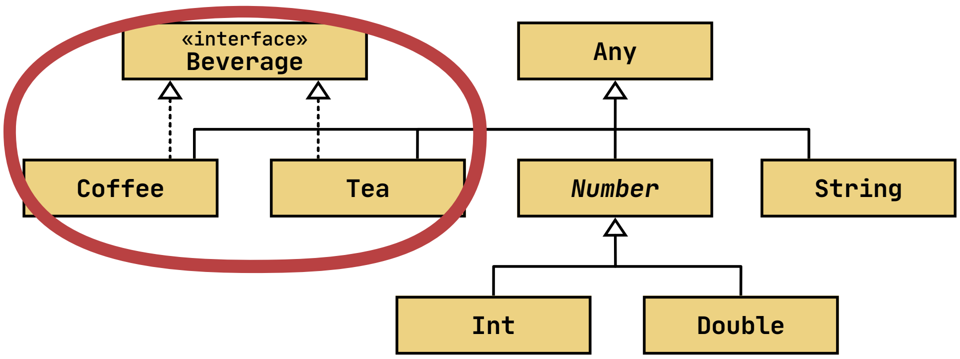
Thankfully, the solution to both of these problems is the same—Eric needs to *constrain* the type parameter so that only **`Beverage`** types can go inside it.

To do this, he can add a **type parameter constraint**, which will ensure that the type argument is of a particular type. To do this, after the name of the type parameter, add a colon and the name of the type that will serve as the **upper bound** for that parameter. For example, to add an upper bound constraint of **`Beverage`**, we can write this.

Type parameter constraint

```
class Mug<T : Beverage>(val beverage: T) {
    val temperature = beverage.idealTemperature
}
```

With this change, **`T`** can only ever be **`Beverage`** or one of its subtypes—**`Tea`** or **`Coffee`**.




Using any other type as a type argument will cause a compiler error.

```
val mugOfString: Mug<String> = Mug("This won't work any more!")
```

*Listing 18.20 - **Error:** Type argument is not within its bounds.*

Also, now that Kotlin knows that the `beverage` property will be some kind of `Beverage`, it's possible to use the properties and functions that the `Beverage` type includes! Because the `Beverage` type includes the `idealTemperature` property, the following code now works.

```
class Mug<T : Beverage>(val beverage: T) {
    val temperature = beverage.idealTemperature
}
```

*Listing 18.21 - The code from Listing 18.18 now compiles without errors.*

If we don't specify the upper bound, Kotlin will assume a default of `Any?`, which means it'll accept any type (including a `null`), as we saw in Listing 18.19. If we know for sure that only certain types should be used for a type argument, it's usually a good idea to give it a type parameter constraint so that the compiler will enforce those rules.

Well, we've learned a lot about generics from Jennifer's bakery café. There are more things we can do with generics, though! Let's take a look at more ways they can be used.

# Generics in Practice

## Using Type Parameters

So far, we've only used a type parameter for a property parameter, but we can use a type parameter almost anywhere that we might normally write a type within the class body.

Frequently, they're used for function parameters and return types, as shown in the following code listing.

```kotlin
class Dish<T>(private var food: T) {
    fun replaceFood(newFood: T) {
        println("Replacing $food with $newFood")
        food = newFood
    }

    fun getFood(): T = food
}
```

*Listing 18.22 - Using a type parameter in multiple places throughout a class.*

## Generics with Multiple Type Parameters

Our examples so far have only included one type parameter, but it's possible for a class to have more than one. For example, a combination order could include one type parameter for **`food`** and one type parameter for the **`beverage`**. When declaring them, just use a different name for each type parameter, and separate them with commas, like this.

```kotlin
class ComboOrder<T : Food, U : Beverage>(val food: T, val beverage: U)
val combo: ComboOrder<Pastry, Tea> = ComboOrder(Pastry.MUFFIN, Tea.GREEN_TEA)
```

*Listing 18.23 - A class with two type parameters.*

Don't go crazy with it, though! It's rare to use more than two or three type parameters in a generic type.[1]

## Generic Interfaces and Superclasses

In addition to classes, interfaces can also be generic. For example, here's a generic interface with one property.

```kotlin
interface Dish<T> {
    val food: T
}
```

*Listing 18.24 - A generic interface.*

When *implementing* this class, we can substitute actual types for the type parameter. For example, we can create a **`BowlOfSoup`** class and instantiate it like this.

```kotlin
class BowlOfSoup(override val food: Soup) : Dish<Soup>
val bowlOfSoup: BowlOfSoup = BowlOfSoup(Soup.TOMATO)
```

*Listing 18.25 - Implementing the generic interface from Listing 18.24.*

[1] Once in a while you might find a library with lots of type parameters in a single generic type. For example, the Arrow functional programming library includes a class called **`Tuple10`** that includes ten type parameters. Most of the time, you shouldn't need that many in your own code, though.

Alternatively, the implementing class can itself declare a type parameter, and relay that to the interface, as shown here.

```
class Bowl<F>(override val food: F) : Dish<F>
val bowlOfSoup: Bowl<Soup> = Bowl(Soup.TOMATO)
```

*Listing 18.26 - Relaying a type parameter to the supertype.*

Similarly, abstract and open classes can also be generic, and extending them works exactly like you would expect.

```
abstract class Dish<T>(val food: T)
class BowlOfSoup(food: Soup) : Dish<Soup>(food)
class Bowl<F>(food: F) : Dish<F>(food)
```

*Listing 18.27 - Extending an abstract generic class.*

Just be sure to provide a type argument when calling the superclass' constructor. And again, that type argument can be a type parameter on the subclass.

## Generic Functions

We've seen how both classes and interfaces can be generic, and how their functions can utilize those type parameters. However, functions can also declare their *own* type parameters. This is especially common for top-level functions—those which are declared outside of a class. In this case, the type parameter is declared between the `fun` keyword and the name of the function.

For example, we can make a top-level function that wraps the constructor of `Mug`.

```
fun <T : Beverage> serve(beverage: T): Mug<T> = Mug(beverage)
```

*Listing 18.28 - Declaring a generic function.*

When calling this function, we can specify the type argument explicitly by putting it in angle brackets to the right of the function name.

```
val mug = serve<Coffee>(Coffee.DARK_ROAST)
```

*Listing 18.29 - Calling a generic function.*

But again, Kotlin can usually infer the type, in which case we can omit it.

```
val mug = serve(Coffee.DARK_ROAST)
```

*Listing 18.30 - Calling a generic function without explicitly specifying the type argument.*

We can even create generic extension functions where the receiver type is a type parameter. For example, we can change the **serve()** function into an extension function.

```
fun <T : Beverage> T.pourIntoMug() = Mug(this)
val mug = Coffee.DARK_ROAST.pourIntoMug()
```

*Listing 18.31 - Declaring and calling a generic extension function, which uses the type parameter as the receiver type.*

We've now got a good understanding of the range of possibilities with generics. Kotlin's standard library also includes lots of generic types and functions, and we've already seen some of them throughout this book. Now that we understand more about what generics are and how they work, let's review a few of them!

# Generics in the Standard Library

## List and Set

Back in Chapter 8, we created **List** and **Set** collections using functions like **listOf()** and **mutableSetOf()**, which are generic functions. As a reminder, here's how we can use the **listOf()** function to create a list of menu items.

```
val menu = listOf("Bagel", "Croissant", "Muffin", "Crumpet")
```

*Listing 18.32 - Creating a list of menu items.*

Much like the **serve()** function above, the code inside the **listOf()** function ends up calling the constructor of a generic class called **ArrayList**. The **ArrayList** class implements the **List** interface, which is also generic.

Most of the time, we just allow Kotlin's type inference to fill in the type arguments for us, but we could explicitly specify them like this.

```
val menu: List<String> = listOf<String>("Bagel", "Croissant", "Muffin", "Crumpet")
```

*Listing 18.33 - Explicitly specifying the type argument for Listing 18.32.*

The type argument to the **listOf()** function is **String**, regardless of whether we explicitly specify it or allow Kotlin to infer the type from the function's arguments. The return type of this function depends on the type argument that it was called with. Since it was called with a type argument of **String**, the return type is **List<String>**.

## Pair

**Pair** is a generic data class that we came across in Chapter 9. It has two type parameters, which determine the type of the two elements that it contains. As you might recall, we can create an instance of **Pair** by calling its constructor.

```
val pair = Pair("Crumpet", "Tea")
```

*Listing 18.34 - Instantiating a* **`Pair`**.

Again, we use type inference most of the time, but we *could* explicitly specify the two type arguments like this.

```
val pair: Pair<String, String> = Pair<String, String>("Crumpet", "Tea")
```

*Listing 18.35 - Explicitly specifying the type arguments for Listing 18.34.*

This listing looks much more intimidating than the previous listing, so it's usually a good idea to just allow Kotlin's type inference to do its thing.

The second way to create a **`Pair`** is to use the **`to()`** infix function, like this.

```
val pair = "Crumpet" to "Tea"
```

*Listing 18.36 - Creating a* **`Pair`** *with the to infix function.*

The **`to()`** function is a generic *extension* function, similar to the **`pourIntoMug()`** function that we created above, except that it has two type arguments. The **`to()`** function exists to make our code read more naturally, so you should never explicitly specify the type arguments when calling it. Just to help demystify the magic, though, this is how you could do that.

```
val pair = "Crumpet".to<String, String>("Tea")
```

*Listing 18.37 - Explicitly specifying the type arguments for Listing 18.36.*

We've seen why generics are helpful, how to create them, how to use them, and a few examples of how they're used in the standard library. Before we wrap up this chapter, let's look at some of the trade-offs involved when we use them.

# Trade-Offs of Generics

As we've seen, generics are a great way to reuse a class or interface, without needing to cast its properties or function results. They come with some trade-offs, though! Here are a few to consider.

## Assignment Compatibility of Generic Types

Back in Listing 18.6 we had a version of the **`Mug`** class that was not generic. Here's what it looked like.

```
class Mug(val beverage: Beverage)
```

*Listing 18.38 - The non-generic version of Mug from Listing 18.6.*

With this code, any `Mug` object can be assigned to any `Mug` variable, regardless of what kind of beverage it holds. For example, we can declare a `Mug` variable, and assign it a mug of coffee or a mug of tea.

```
val mugOfCoffee: Mug = Mug(Coffee.DARK_ROAST)
val mugOfTea: Mug = Mug(Tea.RED_TEA)

var mug: Mug = mugOfCoffee
mug = mugOfTea
```

*Listing 18.39 - A variable with the* `Mug` *type from Listing 18.38 can be assigned either a mug of coffee or a mug of tea.*

Now let's consider a generic version of this class.

```
class Mug<T : Beverage>(val beverage: T)
```

*Listing 18.40 - A generic version of the* `Mug` *class.*

When using this class, we'll end up with parameterized types such as `Mug<Coffee>` and `Mug<Tea>`. By default, these parameterized types are not assignment-compatible.

For example, it's not possible to assign an instance of `Mug<Tea>` to a variable declared with `Mug<Coffee>`.

```
val mugOfCoffee: Mug<Coffee> = Mug(Coffee.DARK_ROAST)
val mugOfTea: Mug<Tea> = Mug(Tea.RED_TEA)

var mug: Mug<Coffee> = mugOfCoffee
mug = mugOfTea
```

*Listing 18.41 - **Error:** Type Mismatch. Required: Mug<Coffee>. Found: Mug<Tea>.*

This isn't surprising. What can catch some developers by surprise, though, is that it's *also* not possible to assign `mugOfCoffee` or `mugOfTea` to a variable that has type `Mug<Beverage>`.

```
val mugOfCoffee: Mug<Coffee> = Mug(Coffee.DARK_ROAST)
val mugOfTea: Mug<Tea> = Mug(Tea.RED_TEA)

var mug: Mug<Beverage> = mugOfCoffee
```

*Listing 18.42 - **Error:** Type Mismatch: Required: Mug<Beverage>. Found: Mug<Coffee>.*

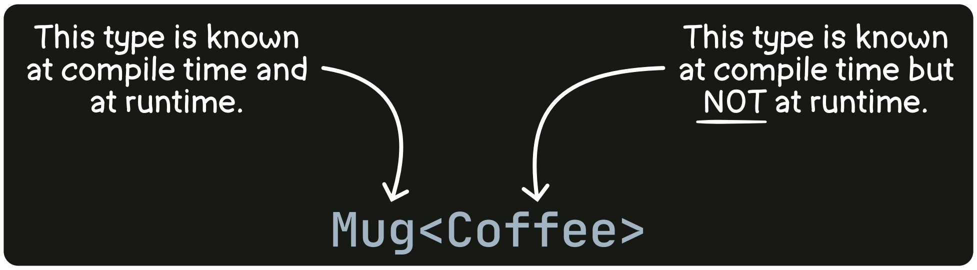
There are some ways that we can work around this, and we'll see those throughout the next chapter! Note that this assignment *does* actually work when assigning directly from a constructor call.

```
val mug: Mug<Beverage> = Mug(Coffee.DARK_ROAST)
```

*Listing 18.43 - Listing 18.42 compiles just fine when directly assigning the result of a constructor call.*

# Type Erasure

One of the most significant trade-offs is **type erasure**. Although an object's type arguments are known at compile-time, they are *erased* before the code runs. In other words, an object's type arguments are *not* known at *runtime*.




Let's look at a few ways that type erasure can affect our code.

## Checking the Type of Type Arguments

One consequence of type erasure is that it's not possible to use **`is`** to check the type of a parameterized type's *type argument* at runtime.

For example, the following code tries to determine whether the **`mug`** instance has a type of **`Mug<Tea>`** or **`Mug<Coffee>`**. This results in a compiler error.

```
val mug: Mug<Beverage> = Mug(Coffee.MEDIUM_ROAST)

when (mug) {
    is Mug<Tea>    -> println("Sipping on tea: ${mug.beverage}!")
    is Mug<Coffee> -> println("Sipping on coffee: ${mug.beverage}!")
}
```

*Listing 18.44 - **Error:** Cannot check for instance of erased type: Mug<Tea>.*

However, it *is* still possible to check the type of a *property* that was declared with a type parameter (such as **`beverage`**), so the following works just fine.

```
val mug: Mug<Beverage> = Mug(Coffee.MEDIUM_ROAST)

when (mug.beverage) {
    is Tea    -> println("Sipping on tea: ${mug.beverage}!")
    is Coffee -> println("Sipping on coffee: ${mug.beverage}!")
}
```

*Listing 18.45 - Checking the type of the beverage rather than the type of the mug.*

## Function Overloads on JVM

Kotlin code can target different kinds of computer systems and environments. Most often, a Kotlin project targets the Java Virtual Machine (JVM), and if you've been following along with the code in this book, that's probably what you've been doing. However, we can also use Kotlin to create programs that run natively on different platforms, like Windows, Linux, Mac, and so on. In fact, we can even create Kotlin code that compiles down to JavaScript!

Once in a while, there's a limitation that affects some of these platforms, but not others. When it comes to type erasure, Kotlin code that targets the JVM has a limitation that doesn't affect native or JavaScript targets: it's not possible to use function overloads where the functions' parameters differ only on their *type arguments*.

For example, in the code to the right, the only difference between the signatures of these two functions is the type argument of their parameters. Compiling this code on the JVM produces an error.

These two function signatures are the same except for the type argument here...

```
fun drinkFrom(mug: Mug<Tea>) = println("Drinking tea")
fun drinkFrom(mug: Mug<Coffee>) = println("Drinking coffee")
```

... and here.

Even with all of these trade-offs, generics are incredibly helpful, so it's important to understand them!

# Summary

The menu at Jennifer's bakery café might change over time, but thanks to Eric's understanding of Kotlin generics, adapting to those changes will be a piece of cake! And now that you know all about generics, you'll be able to handle changes just as smoothly. Here's a quick review of what we learned:

- The problem that generics solve.
- How to declare and use a generic type.
- How type parameter constraints can ensure that only the right kinds of type arguments are used.
- How to use generic interfaces and superclasses.
- How to declare and use generic functions.
- How generics are used in the standard library.
- Trade-offs of using generics.

As we saw in this chapter, the subtyping of generics doesn't always work like we expect—`Mug<Coffee>` isn't naturally a subtype of `Mug<Beverage>`. But with a few small changes, we can make that happen! In the next chapter, we'll explore the fascinating topic of *generic variance!*

Kotlin: An Illustrated Guide

Chapter 19

# Generic Variance

## How can we get more subtypes from our generics?

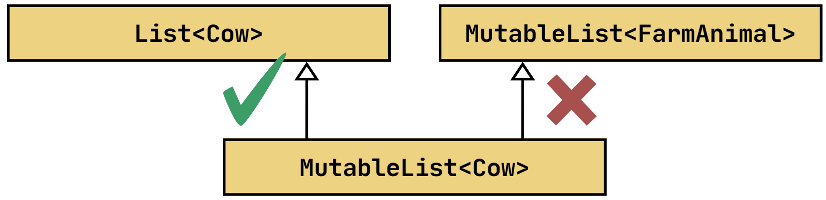
We've seen how we can implement interfaces and extend classes to create subtypes. However, with generic types, we sometimes want to create a subtype based on the type arguments instead of the base types. Kotlin gives us a few different tools to achieve this, and in this chapter we'll learn all about them.

In order to understand how this is possible, we'll first need to understand the principles of variance. Then, we'll look at three simple rules that explain when one parameterized type can be the subtype of another.

To get started, we'll take a stroll through the local park, and make a few purchases from some vending machines!

As we learned in Chapter 12, we can substitute a subtype anywhere that a supertype is expected.

When it comes to generics, though, things don't always work the way we might think. While `MutableList<Cow>` is a subtype of `List<Cow>`, it's not a subtype of `MutableList<FarmAnimal>`.

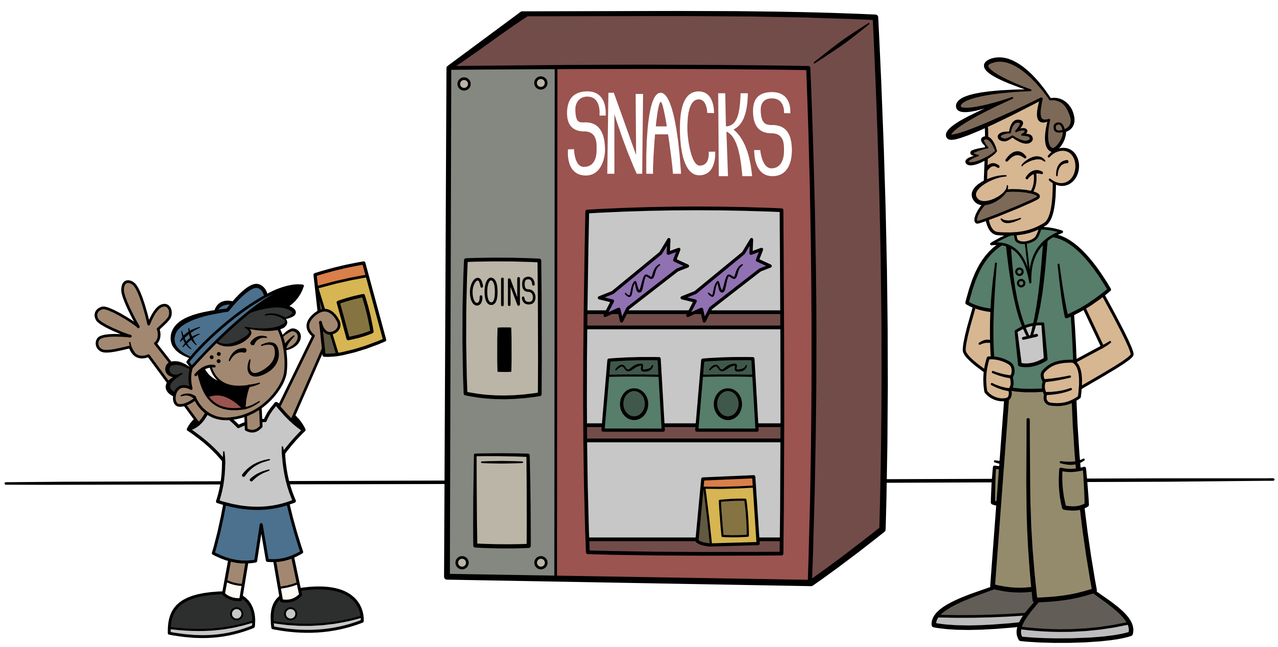



With a little bit of magic, though, we can finagle parameterized types into becoming the subtypes that we need them to be. To do that, we first need to learn about *covariance* and *contravariance*, so let's jump in!

# Covariance

Parker works for the local Parks & Recreation Department. Since the playground is often full of parents with hungry children, he thought, "Let's add a vending machine in the pavilion." So he spoke with Vinnie, who owns a nearby business that sets up and stocks vending machines. "I need a vending machine where kids can put in a *coin* and get back a *snack*", said Parker. Vinnie agreed, so they drew up a contract.


Once the paperwork was signed, Vinnie installed the new vending machine at the park, where customers could insert a coin and receive a random snack, like trail mix, a bag of gummy bears, or a candy bar. The next day, when Parker saw a kid insert a nickel and receive a bag of trail mix from the machine, he smiled to himself, knowing all was well.




A few weeks later, Parker saw Vinnie replacing the machine. Parker was a bit nervous about the change, so he spoke to him. "This new machine will still *accept a coin* and *return a snack*, right?"

“Yes”, began Vinnie, “Trail mix and gummy bears are in short supply, though, so this vending machine is *only* going to return a candy bar. That’s still okay, right?”

Parker thought about it, and finally replied, “As long as it *accepts a coin* and *returns a snack*. A candy bar is a kind of snack, so that should be fine.” After the new machine was substituted for the old one, a child came up, inserted a coin, and received a candy bar. Parker was glad that the new machine did what it was supposed to.

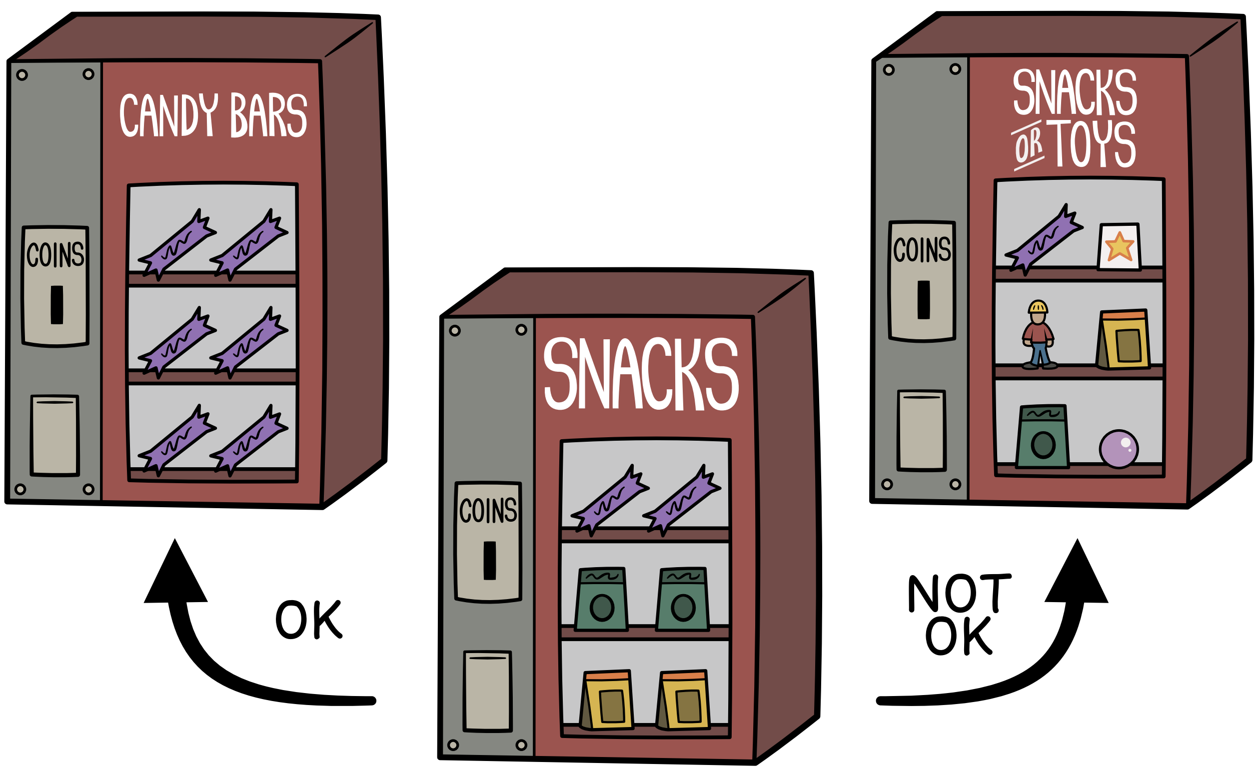

A few weeks passed. One day, Vinnie was at it *again*, replacing the machine with yet *another* one. A few minutes after the installation was complete, an irate father complained to Parker, “What’s wrong with the new vending machine? My hungry kid put in a coin and instead of getting a snack, he got a toy action figure—*he can’t eat a toy!*“

Parker quickly caught up with Vinnie again. When asked about the new machine, Vinnie replied, "Oh, I thought I'd switch out the old vending machine with a new one that returns *either* a snack *or* a toy."

"No, no, no! The contract said the machine would accept a *coin* and return a *snack*. Toys are not snacks!" Realizing that this new machine didn't do what Parker needed, Vinnie agreed to resolve the issue.

As we can see from this story, some substitutions work, but others don't.

- When Vinnie replaced the original vending machine with one that only returns candy bars, everything was fine, because candy bars are still a kind of snack that kids can eat.
- However, when he replaced it with the machine that returns either a snack *or* a toy, he broke his contract—the machine no longer returned *only* snacks.

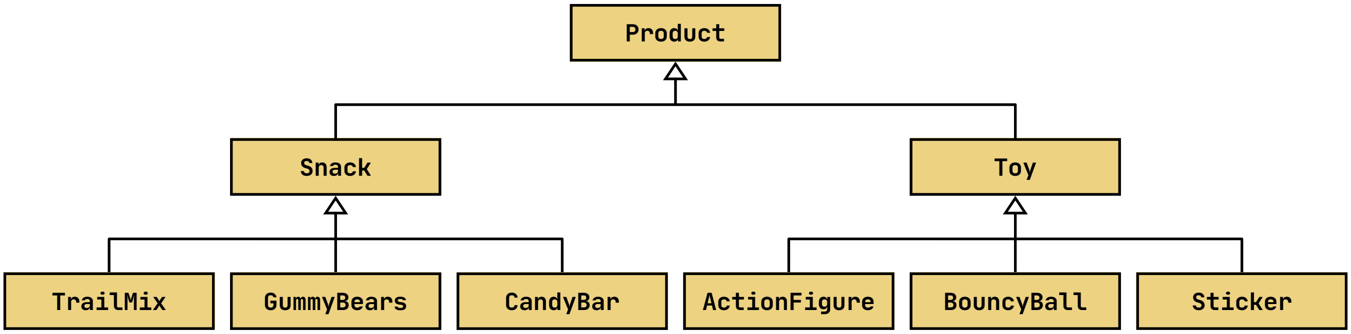



This brings up some important points for us to explore about *substitution* in Kotlin. To get started, let's model the first vending machine that Vinnie provided—the one that accepted a coin and returned a snack.

```
open class VendingMachine {
    open fun purchase(money: Coin): Snack = randomSnack()
}
```

*Listing 19.1 - A simple* **`VendingMachine`** *class that accepts a* **`Coin`** *and returns a* **`Snack`**.

Although this chapter won't include definitions for **`Snack`** and its related types, here's a class diagram showing their type hierarchy.




Now let's model Vinnie's *second* vending machine by extending the one above. This one looks almost identical to it, but instead of a random snack, it only ever returns a candy bar.

```kotlin
class CandyBarMachine : VendingMachine() {
    override fun purchase(money: Coin): Snack = CandyBar()
}
```

*Listing 19.2 - Modeling Vinnie's second vending machine by extending the first.*

Any code that expects a **`VendingMachine`** can work with a **`CandyBarMachine`**, because it's a subtype of **`VendingMachine`**—it still *accepts a coin* and *returns a snack*, just like **`VendingMachine`** does. Because of this, we can substitute a **`CandyBarMachine`** for a **`VendingMachine`**. In other words, we can assign a **`CandyBarMachine`** to a variable declared as a **`VendingMachine`**.

```kotlin
val machine: VendingMachine = CandyBarMachine()
```

supertype

subtype

Similarly, we can send it as an argument to a function that expects a **`VendingMachine`**.

supertype

```kotlin
fun purchaseSnackFrom(machine: VendingMachine) = machine.purchase(Dime())
val snack = purchaseSnackFrom(CandyBarMachine())
```

subtype

As we saw in the story, a **`CandyBar`** is a kind of **`Snack`**, so it's also safe to *declare* that the **`CandyBarMachine`** only returns **`CandyBar`** objects. Let's take the code from Listing 19.2 and update the return type.

```kotlin
class CandyBarMachine : VendingMachine() {
    override fun purchase(money: Coin): CandyBar = CandyBar()
}
```

*Listing 19.3 - Declaring that* **`CandyBarMachine`** *only returns* **`CandyBar`** *objects.*

As the story revealed, this only works one way. When Vinnie tried to replace the vending machine with one that returned a product that could be *either* a snack *or* a toy, he broke his contract. Kids expect to be able to eat anything that the vending machine provides, but toys aren't edible!

The same principle holds true in Kotlin—a subclass can't return a more *general* type than the one declared in its supertype. For example, if we create a **`ToyOrSnackMachine`** that tries to return any kind of **`Product`**, we'll get a compile-time error.

```
class ToyOrSnackMachine : VendingMachine() {
    override fun purchase(money: Coin): Product = randomToyOrSnack()
}
```

*Listing 19.4 - **Error:** Return type is 'Product', which is not a subtype of overridden.*

## By the Way: Returning Supertypes

When a **`CandyBarMachine`** is assigned to a variable declared as **`CandyBarMachine`**, it'll return the candy bar as a **`CandyBar`**. However, when a **`CandyBarMachine`** is assigned to a **`VendingMachine`** variable, it'll return the candy bar as a **`Snack`**. Of course, you can still cast it from **`Snack`** to **`CandyBar`**.

```
val candyBarMachine: CandyBarMachine = CandyBarMachine()
val vendingMachine: VendingMachine = CandyBarMachine()

val candyBar: CandyBar = candyBarMachine.purchase(Dime())
val snack: Snack = vendingMachine.purchase(Dime())
```

Most classes and interfaces associate with other types. Associated types can appear in a variety of places—as function parameter types, function return types, property types, and so on. For example, the **`VendingMachine`** class associates with two other types.

- **`Coin`** - the type of the parameter in **`purchase()`**.
- **`Snack`** - the return type of **`purchase()`**.

class type

```
open class VendingMachine {
    open fun purchase(money: Coin): Snack = randomSnack()
}
```

associated type associated type

The **`VendingMachine`** class can have supertypes and subtypes. Similarly, the associated types **`Coin`** and **`Snack`** can also have their *own* supertypes and subtypes.

The nature of the relationship between the type hierarchy of **`VendingMachine`** and the type hierarchy of its associated types can be described by **variance**. As we look at the code of **`VendingMachine`** and **`CandyBarMachine`** side by side, we can see that relationship emerge.

is a subtype of

```
open class VendingMachine {
    open fun purchase(money: Coin): Snack = ...
}
```

```
class CandyBarMachine : VendingMachine() {
    override fun purchase(money: Coin): CandyBar = ...
}
```

is a subtype of

Specifically, we can see that as we make a more *specific* **`VendingMachine`**, we can return a more *specific* **`Snack`** from the **`purchase()`** function.

Because they become more specific *together*, this kind of variance is called **covariance**, where "co-" is a prefix that means "together".

When talking about variance, developers normally say it one of these ways:

- "A type is covariant *with regard to* its return types."
- "A type is covariant *on* its return types."

To sum up this section, just remember that within a subtype (e.g., **`CandyBarMachine`**) a function can return a more *specific* type (e.g., **`CandyBar`**) than declared in its supertype, but it cannot return a more *general* type (e.g., **`Product`**).

The adventures of Parker and Vinnie continue, though! Brace yourself—Vinnie is about to try substituting a few more vending machines!

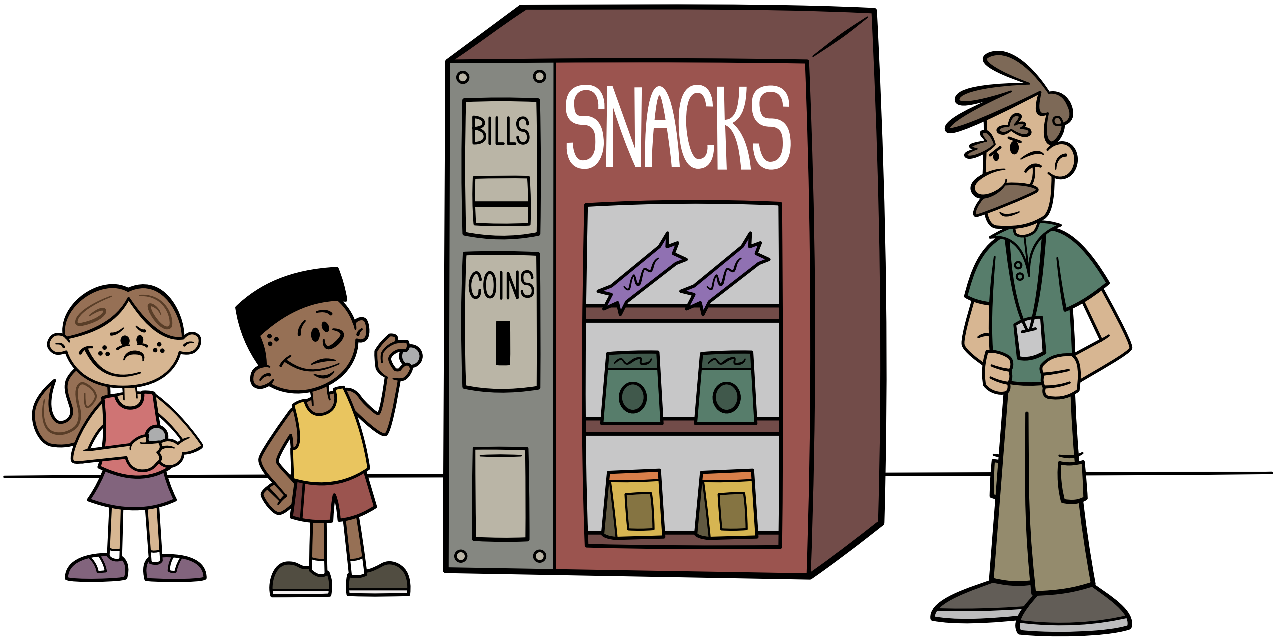
# Contravariance

A few weeks later, Parker noticed that Vinnie was replacing the machine yet again. "We're upgrading our machines so that they accept both coins *and* bills," he explained.

Parker scratched his head while he thought about it. "Well, I guess that's fine. As long as the machine still *accepts a coin* and *returns a snack*."

After the new machine was installed, a kid walked up, inserted a dime, and got a snack from the machine. "Great," Parker thought to himself. "Everything is still good."

Things continued well over the next few weeks. Even though this new vending machine had a bill acceptor, none of the kids ever used it, because they only ever had coins.

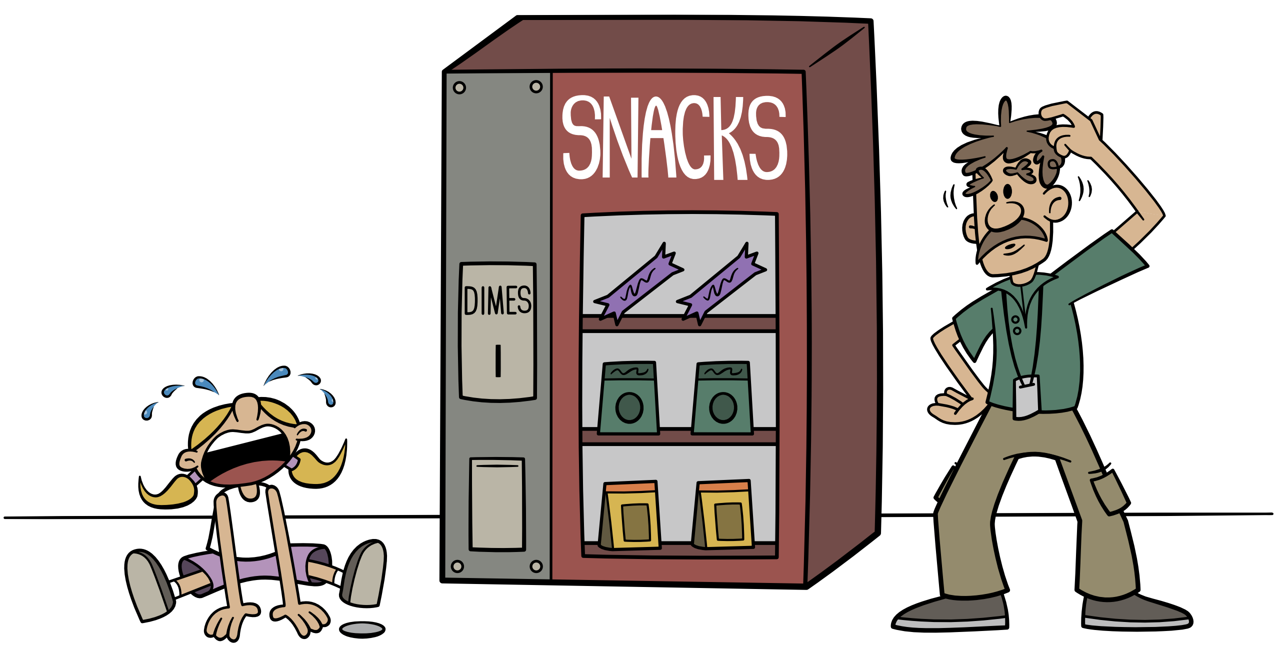



Wouldn't you know it—a few weeks later, Parker saw Vinnie replacing the machine one more time. Parker shrugged it off and continued on his way.

Ten minutes later, though, a young girl was crying next to the snack machine.

"What's wrong?" he asked her.

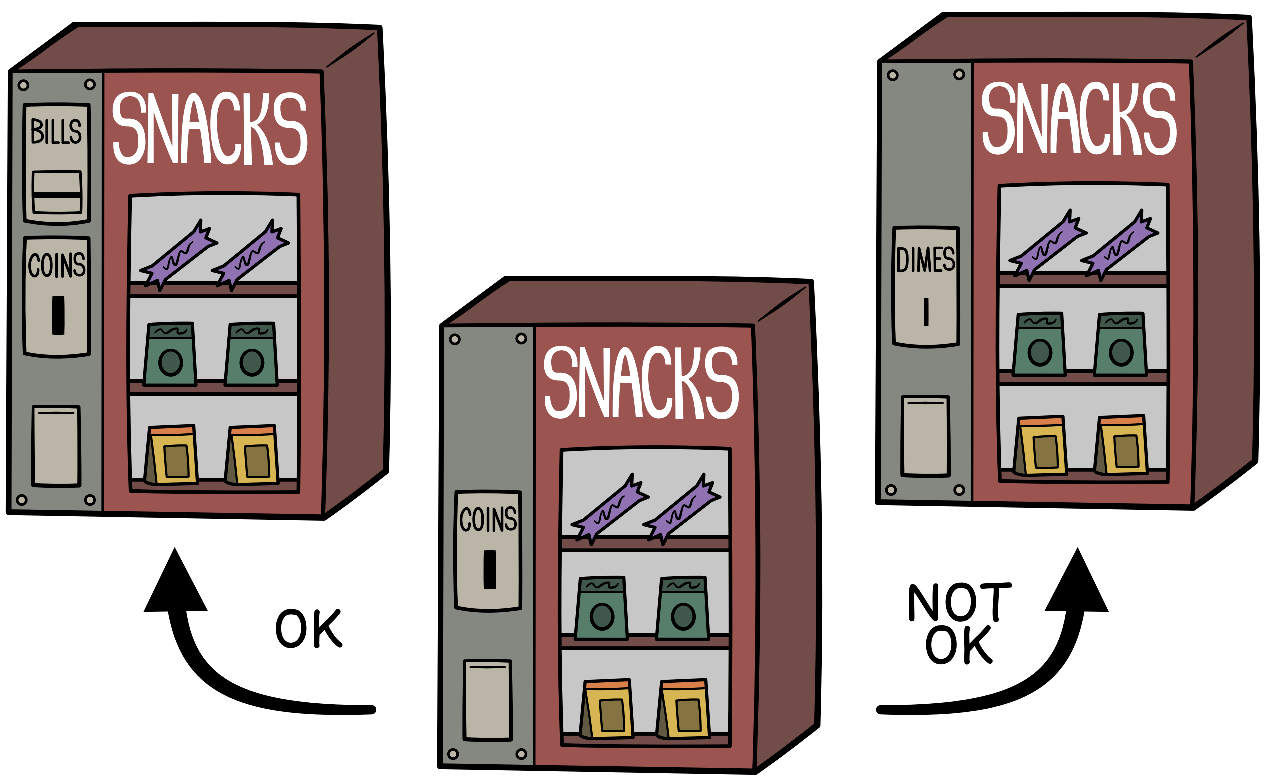
"I wanted a snack. I have a nickel, but this machine only accepts a dime!" Parker looked at the new vending machine, and sure enough, it *only* had a slot for dimes, but not any other kind of coin.



Parker complained to Vinnie again. "No, no, no! The contract said the machine would *accept a coin* and *return a snack*. A nickel is a kind of coin, so the machine still needs to accept it!" Embarrassed, Vinnie put back the previous vending machine.

This story shows again that some substitutions work, and some don't.

- When Vinnie replaced the original vending machine with the one that accepted both coins and bills, everything still worked, because it still accepted coins. The kids only ever had coins on them, so they never actually *used* the bill acceptor, but there was no harm in the machine having one, as long as it could still accept coins.
- However, when Vinnie replaced it with the machine that accepted only dimes, he broke his contract—the machine no longer accepted nickels, quarters, or any other kind of coin.

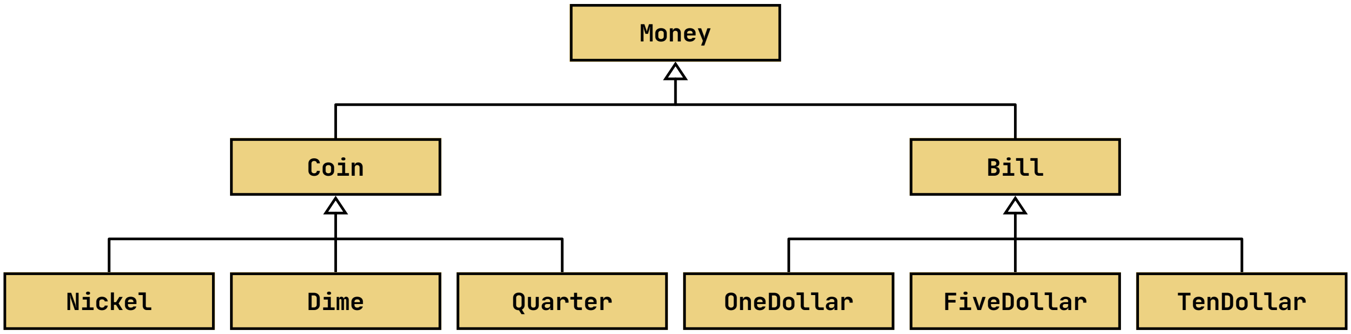



This illustrates additional points about substitution. Let's take a look at the original `VendingMachine` we created back in Listing 19.1.

```
open class VendingMachine {
    open fun purchase(money: Coin): Snack = randomSnack()
}
```

*Listing 19.5 - The* `VendingMachine` *class from Listing 19.1.*

As with `Snack`, this chapter won't include any class definitions for `Coin` and its type hierarchy, but here's a class diagram showing how they relate.




As we saw, it was safe for Vinnie to replace the coin-based vending machine with one that can accept *either* coins *or* bills. Likewise, it would be safe for Kotlin to allow a subtype to declare a more *general* parameter type.

But guess what? If we try changing the parameter type from **`Coin`** to **`Money`**, we'll get a compiler error!

```
class AnyMoneyVendingMachine : VendingMachine() {
    override fun purchase(money: Money): Snack = randomSnack()
}
```

*Listing 19.6 - **Error:** 'purchase' overrides nothing.*

Again, this would be perfectly safe for Kotlin's type system to allow. So why does this cause a compiler error?

As you might recall, Kotlin allows us to overload a function—a class or interface can have multiple functions that have the same name, as long as their parameter types differ. In order to support this feature, Kotlin won't allow us to change the type of a function parameter in subtypes, as we're trying to do above.

One way to fix this is to simply remove the **`override`** keyword, which means we'll be *overloading* the function instead of *overriding* it.

```
class AnyMoneyVendingMachine : VendingMachine() {
    fun purchase(money: Money): Snack = randomSnack()
}
```

*Listing 19.7 - Overloading the **`purchase()`** function from the **`VendingMachine`** superclass.*

Just keep in mind that when we do this, we end up with *two* **`purchase()`** functions, each with its own body—one in **`AnyMoneyVendingMachine`** and one in **`VendingMachine`**.

So Kotlin's overloading feature is getting in the way. Overloading only applies to functions declared with the **`fun`** keyword, though, so to work around this, we can change **`purchase()`** from a function to a property that has a function type, like this.

```
open class VendingMachine {
    open val purchase: (Coin) -> Snack = { randomSnack() }
}
```

*Listing 19.8 - Rewriting **`purchase()`** as a property with a function type.*

With this change, we can rewrite **`AnyMoneyVendingMachine`** to override that property.

```
class AnyMoneyVendingMachine : VendingMachine() {
    override val purchase: (Coin) -> Snack = { randomSnack() }
}
```

*Listing 19.9 - Overriding the* **`purchase`** *property in the subclass.*

And finally, we can replace the Coin parameter type with Money.

```
class AnyMoneyVendingMachine : VendingMachine() {
    override val purchase: (Money) -> Snack = { randomSnack() }
}
```

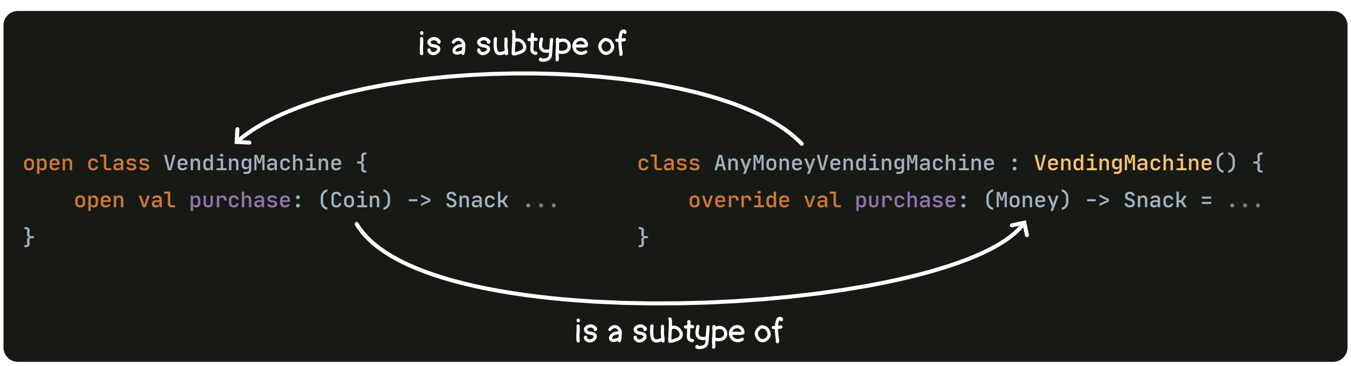
*Listing 19.10 - Replacing the parameter with a more general type.*

With this, we can assign an instance of **`AnyMoneyVendingMachine`** to a variable whose type is **`VendingMachine`**. When assigned to a **`VendingMachine`** variable, it can only accept a **`Coin`**. But when assigned to an **`AnyMoneyVendingMachine`**, it can accept either a **`Coin`** or a **`Bill`**.

```
val vendingMachine: VendingMachine = AnyMoneyVendingMachine()
val anyMoneyMachine: AnyMoneyVendingMachine = AnyMoneyVendingMachine()

val snack1: Snack = vendingMachine.purchase(Dime())
val snack2: Snack = anyMoneyMachine.purchase(Dime())
val snack3: Snack = anyMoneyMachine.purchase(OneDollarBill())
```

*Listing 19.11 - The object's type affects which argument types the* **`purchase()`** *function accepts.*

As we did earlier, we can put these two classes side by side and discover the nature of the variance between the class type and the return type of **`purchase()`**.




This time, we can see that as we make a more *specific* **`VendingMachine`**, we can accept a more *general* parameter type in **`purchase`**.

The arrows above are pointing in *opposite* directions, so this kind of variance is called **contravariance**.

As you recall from the story, when Vinnie tried to replace the vending machine with one that accepted a more *specific* kind of coin, he broke his contract. Similarly, we can't create a subclass that accepts a more specific type than its superclass did.

For example, if we update **`purchase`** so that its parameter type is **`Dime`**, we'll get a compiler error.

```
class AnyMoneyVendingMachine : VendingMachine() {
    override val purchase: (Dime) -> Snack = { randomSnack() }
}
```

*Listing 19.12 - **Error:** Property type is (Dime) -> Snack, which is not a subtype of overridden (Coin) -> Snack.*

So, we learned from this story that a subtype can declare that it accepts a more *general* type, but not a more *specific* type.

Now that we understand variance—including covariance and contravariance—it's time to revisit what we learned, and see how these concepts apply to *generics*.

# What Makes a Subtype a Subtype?

Whenever Vinnie replaced one vending machine with another, everything was fine as long as the new machine did *everything* that the contract said it would. Specifically, the contract stated that the vending machine must *accept a coin* and *return a snack*. If the new machine did those things, then it was a suitable substitute. On the two occasions when it broke the contract, it was not a suitable substitute.

So what makes a subtype a subtype? *The ability to substitute it for one of its supertypes.* A subtype must *fully comply with* the contract of its supertype. Specifically, this means it must obey the following three rules:[1]

1. The subtype must have all of the same *public properties and functions* as its supertype.
2. Its function *parameter types* must be the *same as or more general than* the ones in its supertype.
3. Its function *return types* must be the *same as or more specific than* the ones in its supertype.

We usually think of a subtype as a class that extends another class, an interface that extends another interface, or a class that implements an interface. In all three of these cases, Kotlin's type system will ensure that the subclass follows the three rules above. However, when it comes to parameterized types—such as **`VendingMachine<Snack>`** and **`VendingMachine<CandyBar>`**—we can't *explicitly* declare that one type is a subtype of another.

[1] The goal of this chapter is to explain generic variance, so these three rules are focused on the structure of the types. More strictly speaking, though, the behaviors of the classes should be compatible, as well. (See Liskov, B., & Wing, J. M. (1994). A behavioral notion of subtyping. ACM Transactions on Programming Languages and Systems, 16(6), 1811-1841). Also, Meilir Page-Jones observes these three rules more generally through the lens of preconditions, postconditions, and class invariants. (Page-Jones, M. (2000). Fundamentals of Object-Oriented Design in UML. Addison-Wesley Professional. p. 283).

To help demonstrate this, let's convert **VendingMachine** to a generic class. As a part of this change, we'll add a **snack** constructor parameter, which is the snack that will get returned when the **purchase()** function is called.

```
class VendingMachine<T : Snack>(private val snack: T) {
    fun purchase(money: Coin): T = snack
}
```

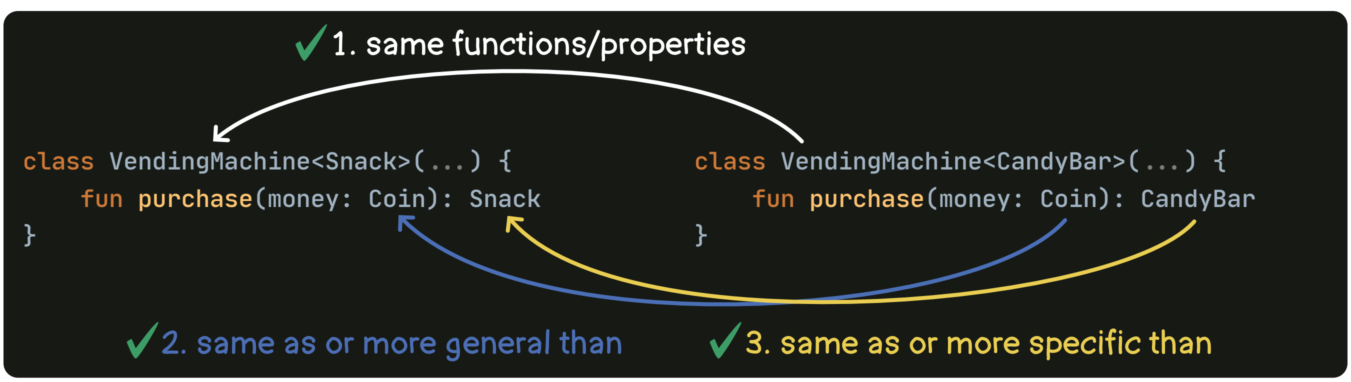
*Listing 19.13 - A generic version of the* **VendingMachine** *class.*

## By the Way: No More Random Snacks

Since the return type of **purchase()** varies depending on the type argument, we can't just use **randomSnack()** any more - the snack has to have the same type as the type argument. For example, in **VendingMachine<CandyBar>**, the **purchase()** function must return a **CandyBar**, not a **Snack**. Setting this value in the constructor is a simple way to do this. If you prefer, you could change the **snack** property to a function type that constructs new snacks. e.g., **private val snack: () -> T**.

As we learned in the [last chapter] we can create parameterized types from this generic, such as **VendingMachine<Snack>** and **VendingMachine<CandyBar>**. Even though we can't explicitly declare that **VendingMachine<CandyBar>** is a subtype of **VendingMachine<Snack>**, it would be perfectly safe for this to be the case, because it wouldn't break the contract—all three rules above would be satisfied.

We can visualize this by imagining what the *effective* parameterized type would look like. In other words, let's take the generic **VendingMachine** above, and everywhere that the type parameter appears, we'll replace it with the type argument. Are all three rules satisfied?




So, **VendingMachine<CandyBar>** fully satisfies the contract of **VendingMachine<Snack>**, which means it's safe for it to be one of its subtypes. This won't just happen automatically, though. For example, if we try assigning it to a variable declared as **VendingMachine<Snack>**, we'll get a compiler error.

```
val candyBarMachine: VendingMachine<CandyBar> = VendingMachine(CandyBar())
val vendingMachine: VendingMachine<Snack> = candyBarMachine
```

*Listing 19.14 - **Error:** Type Mismatch. Required: VendingMachine<Snack>. Found: VendingMachine<CandyBar>.*

So, `VendingMachine<CandyBar>` won't be a subtype of `VendingMachine<Snack>` until we tell Kotlin our intent, which requires us to do one more thing.

### Technically Speaking: Variance and Properties

To keep things simple, this chapter focuses mainly on variance as it relates to function parameter types and return types. However, variance does still apply to properties as well.

- A property that's declared with `val` can be overridden and given a more specific type, just as we can do with a function return type.
- A property that's declared with `var` can also be overridden, but its type must be *exactly the same* as what's declared in its supertype. We can't replace it with a more specific or more general type.

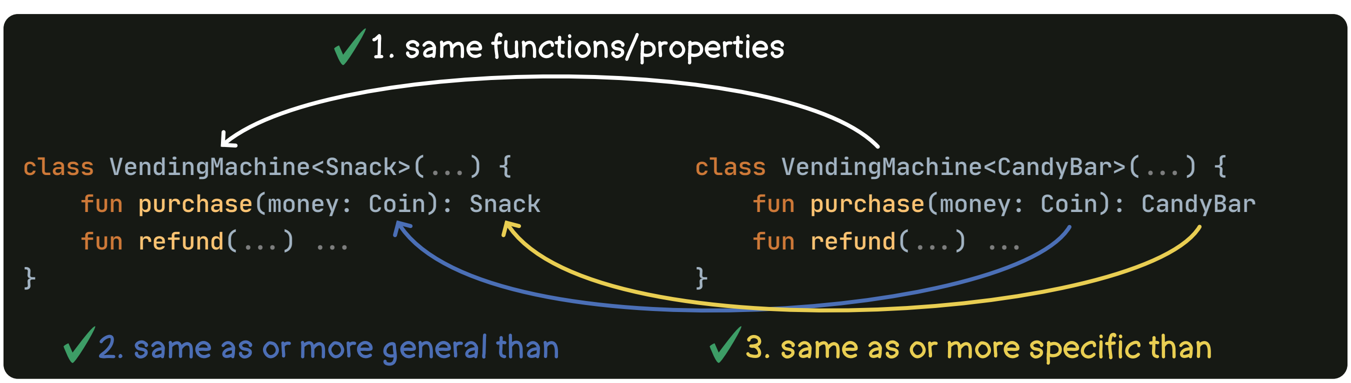
# Variance Modifiers

As we saw above, `VendingMachine<CandyBar>` fully satisfies the contract of `VendingMachine<Snack>`, so it *should* be possible for it to be a subtype of it. However, a type parameter can *potentially* be used in lots of places throughout the body of a generic type. It could be used as the return type of a function, as the parameter of a function, as the type of a property, and so on. Let's consider what would happen if we were to add a `refund()` function to the `VendingMachine` interface.

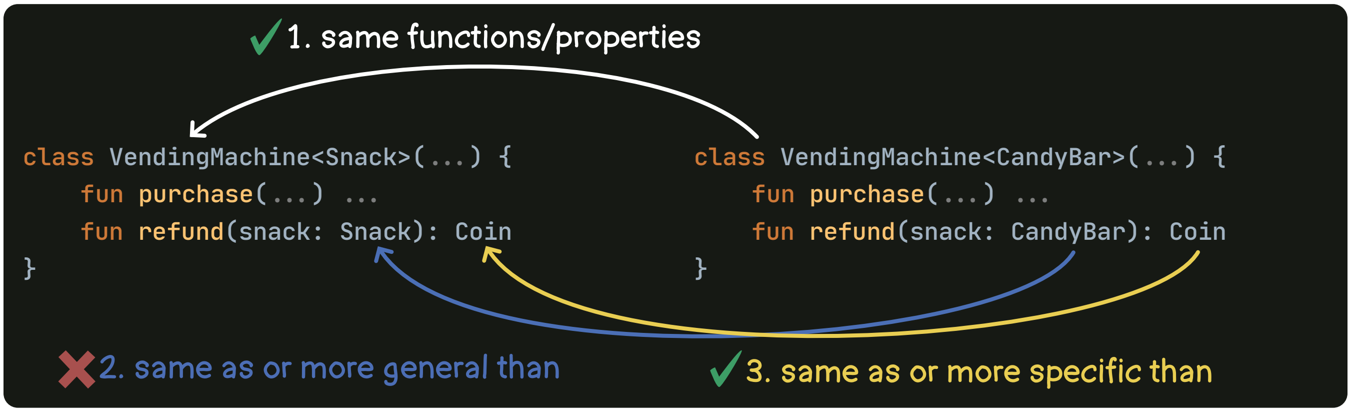
```
class VendingMachine<T : Snack>(private val snack: T) {
    fun purchase(money: Coin): T = snack
    fun refund(snack: T): Coin = Dime()
}
```

*Listing 19.15 - Adding a* `refund()` *function to the* `VendingMachine` *class.*

In this case, the type parameter `T` appears *both* as a function result type *and* as a function parameter type. Would this version of `VendingMachine<CandyBar>` satisfy the contract of `VendingMachine<Snack>`? Let's compare the effective parameterized types again. First, let's look at the `purchase()` function.



As before, when it comes to the `purchase()` function, `VendingMachine<CandyBar>` satisfies the contract of `VendingMachine<Snack>`. So far so good. Now let's look at the `refund()` function.




Yikes! Even though the *return type* of `refund()` satisfies the contract, the *parameter type* does not, because `CandyBar` is not the "same as or more general than" `Snack`—it's more *specific*. So, if `VendingMachine<T>` includes the `refund()` function, then `VendingMachine<CandyBar>` *cannot* be a subtype of `VendingMachine<Snack>`.

If Kotlin is going to treat `VendingMachine<CandyBar>` as a subtype of `VendingMachine<Snack>`, we have to promise Kotlin that we *won't* use this type parameter as a function parameter type, like we did in `refund()`. Instead, it can only publicly appear in **out-positions**—in other words, as a function return type, or as the type of a read-only property.

To make this promise, we can add a **variance modifier** to the type parameter. Kotlin has two variance modifiers—let's check them out.

## The `out` modifier

The first variance modifier is named `out`, and it's our way of telling Kotlin that this type parameter will only appear in an *out-position*. Let's add the `out` modifier to type parameter `T`.

```
class VendingMachine<out T : Snack>(private val snack: T) {
    fun purchase(money: Coin): T = snack
}
```

*Listing 19.16 - Adding an `out` modifier to a type parameter.*

This simple change is all that's needed to get the code from Listing 19.14 to compile without errors—`VendingMachine<CandyBar>` is now a subtype of `VendingMachine<Snack>`!

```
val candyBarMachine: VendingMachine<CandyBar> = VendingMachine(CandyBar())
val vendingMachine: VendingMachine<Snack> = candyBarMachine
```

*Listing 19.17 - The code from Listing 19.14 now compiles without errors.*

As we saw earlier in this chapter, a type is *covariant* with its associated function *result types*. So by ensuring that this type parameter is *only used as a result type*, we know that it's safe for the **`VendingMachine`** type to be covariant with **`T`**.

Again, the **`out`** modifier is a promise to Kotlin that we will only use the type parameter in the out-position. If we try to use this same type parameter publicly in an **in-position**—that is, as a function parameter type—then we'll get a compiler error. To demonstrate this, we can pop in the **`refund()`** function from Listing 19.15, and watch as the compiler calls us out for breaking our promise.

```
class VendingMachine<out T : Snack>(private val snack: T) {
    fun purchase(money: Coin): T = snack
    fun refund(snack: T): Coin = Dime()
}
```

*Listing 19.18 - **Error:** Type parameter **`T`** is declared as **`out`** but occurs in **`in`** position.*

So, by adding the **`out`** modifier to the type parameter, we've got the *advantage* that **`VendingMachine<CandyBar>`** is now a subtype of **`VendingMachine<Snack>`**, but we've got the *disadvantage* that we can no longer use **`T`** in an *in-position*.

## The `in` modifier

As you probably guessed, Kotlin includes a complement to the **`out`** modifier, called **`in`**. But before we look at it, let's shake things up in the **`VendingMachine`** class. Instead of a type parameter for its *snack* type, let's use the type parameter for its *money* type.

```
class VendingMachine<T : Money> {
    fun purchase(money: T): Snack = randomSnack()
}
```

*Listing 19.19 - Changing the type parameter to represent the money instead of the snack.*

Similar to before, we can try to assign an instance of **`VendingMachine<Money>`** to **`VendingMachine<Coin>`**, but we'll get an error.

```
val moneyVendingMachine: VendingMachine<Money> = VendingMachine()
val coinVendingMachine: VendingMachine<Coin> = moneyVendingMachine
```

*Listing 19.20 - **Error:** Type Mismatch. Required: VendingMachine<Coin>. Found: VendingMachine<Money>.*

Although **`T`** is only being used in the *in-position*, we still have to tell Kotlin by using the **`in`** variance modifier.

```
class VendingMachine<in T : Money> {
    fun purchase(money: T): Snack = randomSnack()
}
```

*Listing 19.21 - Adding an **`in`** variance modifier to the type parameter.*

With this change, the code from Listing 19.20 successfully compiles!

```
val moneyVendingMachine: VendingMachine<Money> = VendingMachine()
val coinVendingMachine: VendingMachine<Coin> = moneyVendingMachine
```

*Listing 19.22 - The code from Listing 19.20 now compiles without any errors.*

As with the **`out`** modifier, we've made a trade-off here: when we declare a type parameter with the **`in`** modifier, we're promising Kotlin that it will only ever appear in the *in-position*. Again, if we add a **`refund()`** function, we would need **`T`** in the *out-position*—as that function's return type—which would cause a compiler error.

```
class VendingMachine<in T : Money>(private val money: T) {
    fun purchase(money: T): Snack = randomSnack()
    fun refund(snack: Snack): T = money
}
```

*Listing 19.23 - **Error:** Type parameter T is declared as 'in' but occurs in 'out' position in type T.*

To summarize:

- The **`out`** modifier can be used to ensure that the type parameter will only publicly appear in an out-position, which makes it safe for covariance.
- Conversely, the **`in`** modifier can be used to ensure that it will only publicly appear in an in-position, so that it's safe for contravariance.

In order to keep things simple, we've only used one type parameter at a time so far in this chapter. It's entirely possible to have multiple type parameters, though, and when we do, we can use a variance modifier on each one. Let's see how that looks.

# Variance on Multiple Type Parameters

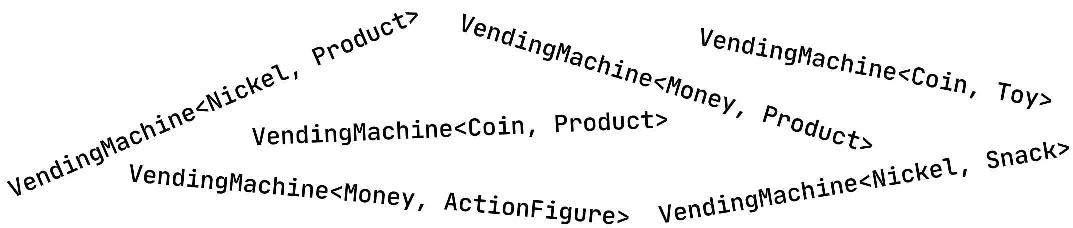
It's important to note that generic variance doesn't describe the type as a whole—it describes the relationship of the *type to one of its type parameters*. So, it can be covariant on one and contravariant on another. Instead of a single type parameter for either the **`Money`** or **`Product`**, let's include one for each.

```
class VendingMachine<in T : Money, out R: Product>(private val product: R) {
    fun purchase(money: T): R = product
}
```

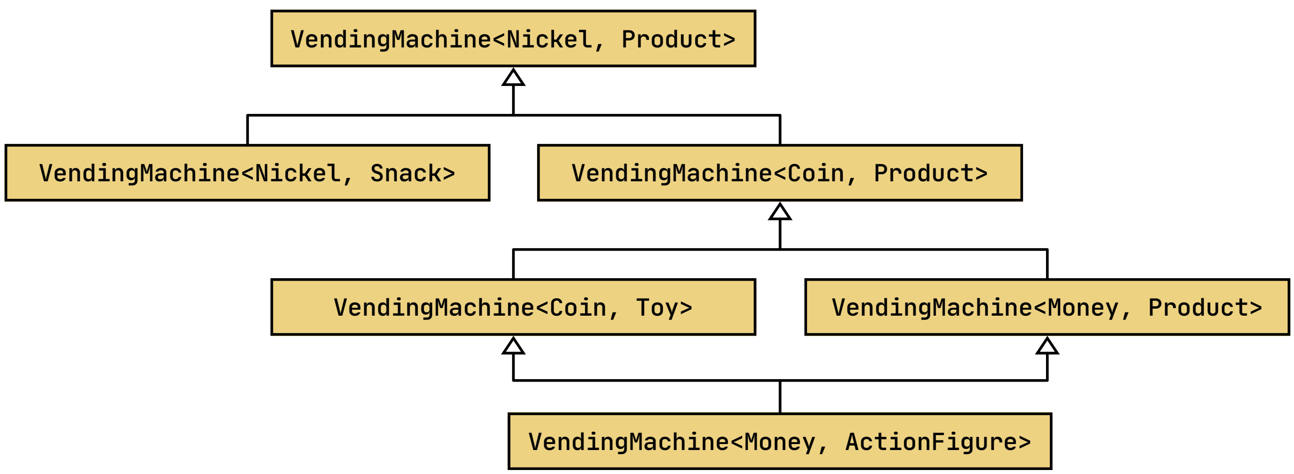
*Listing 19.24 - Variance on multiple type parameters in one class.*

In this code, **`VendingMachine`** is *contravariant* with respect to **`T`**, and *covariant* with respect to **`R`**. From this generic class, we could instantiate a wide range of parameterized types.

Some of them would include:




With two type parameters, all those types of money, and all those types of products, it's easy to get lost in which of the parameterized types are subtypes of the others. Just remember that a subtype must *fully support* the contract of its supertype. Here's how the type hierarchy looks for the parameterized types above.




It's helpful to know that we can apply variance modifiers to multiple type parameters. For the rest of this chapter, though, we'll go back to a single type parameter in order to keep the examples easy to follow.

We've seen how the **in** and **out** modifiers create variance, but we've also seen the trade-offs—type parameters declared with **in** can't be used as a result type, and those declared with **out** can't be used as a function parameter type. But sometimes, those trade-offs just won't cut it. When that's the case, we can still get some of the benefits of variance by using *type projections*.

# Type Projections

So far, we've been able to get **VendingMachine<CandyBar>** to be a subtype of **VendingMachine<Snack>** by using variance modifiers on our type parameters. Let's update the code from Listing 19.16 so that it works with any kind of **Product** and any kind of **Money**.

```
class VendingMachine<out T : Product>(private val product: T) {
    fun purchase(money: Money): T = product
}
```

*Listing 19.25 - Updating the* **VendingMachine** *to work with any kind of* **Product** *and any kind of* **Money**.

In this code, we've got **`out`** on the type parameter again. Because we put this variance modifier where the type parameter is *declared*, this is called **declaration-site variance**. We can't always use declaration-site variance, though. For example, what if we really, truly need that **`refund()`** function from Listing 19.18?

```kotlin
class VendingMachine<T : Product>(private val product: T) {
    fun purchase(money: Money): T = product
    fun refund(product: T): Money = Dime()
}
```

*Listing 19.26 - Adding the* **`refund()`** *function to our new* **`VendingMachine`** *class.*

We can't use the **`out`** variance modifier, because **`T`** is used in an in-position in **`refund()`**. And we can't use the **`in`** modifier, because it's used in an out-position in **`purchase()`**. Are we just out of luck, here? Does this mean that **`VendingMachine<CandyBar>`** will never be considered a subtype of **`VendingMachine<Snack>`**?

Thankfully, Kotlin provides a second option. Instead of using a variance modifier on a type *parameter*, we can use it on a type *argument*. To demonstrate this, let's start with a function that accepts a **`VendingMachine<Snack>`**.

```kotlin
fun getSnackFrom(machine: VendingMachine<Snack>): Snack {
    return machine.purchase(Dime())
}
```

*Listing 19.27 - A function that accepts a* **`VendingMachine<Snack>`**.

Since there are no variance modifiers on the type parameter in Listing 19.26, **`VendingMachine<CandyBar>`** is not a subtype of **`VendingMachine<Snack>`**, so we won't be able to call the function with an instance of **`CandyBarMachine`**.

```kotlin
val candyBarMachine: VendingMachine<CandyBar> = VendingMachine(CandyBar())
getSnackFrom(candyBarMachine)
```

*Listing 19.28 - **Error:** Type Mismatch. Required: VendingMachine<Snack>; Found: VendingMachine<CandyBar>.*

Now let's add an **`out`** modifier to the type *argument* in the **`getSnackFrom()`** function, like this.

```kotlin
fun getSnackFrom(machine: VendingMachine<out Snack>): Snack {
    return machine.purchase(Dime())
}
```

*Listing 19.29 - Adding the* **`out`** *variance modifier to a type argument.*

With this change, the code from Listing 19.28 compiles successfully!

```kotlin
val candyBarMachine: VendingMachine<CandyBar> = VendingMachine(CandyBar())
getSnackFrom(candyBarMachine)
```

*Listing 19.30 - The code from Listing 19.28 now compiles successfully.*

When we put a variance modifier on a type *argument* rather than a type *parameter*, we create variance at the place in our code where we're *using* the type (e.g., **`getSnackFrom()`**) instead of where we *declared* it (e.g., **`VendingMachine`**). For this reason, we call this **use-site variance**.

Just like declaration-site variance, use-site variance comes with trade-offs. As we'll see in a moment, because the **`machine`** parameter has the **`out`** modifier, we won't be able to call the **`refund()`** function inside the body of this function. Thankfully, the body of this function has no need for the **`refund()`** function, so this trade-off is entirely acceptable here!

```
fun getSnackFrom(machine: VendingMachine<out Snack>): Snack {
    return machine.purchase(Dime())
}
```

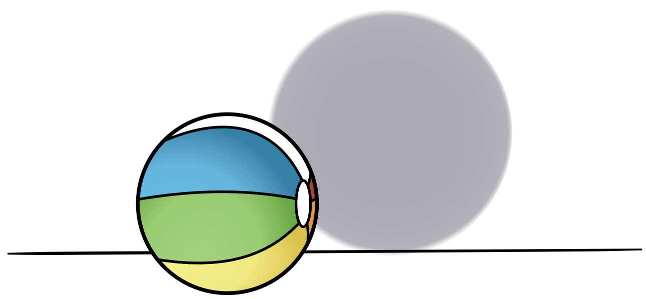
This function body can't call refund(), but it also has no need to.

Keep in mind that *declaration-site variance* applies to the whole project, but *use-site variance* works only in a specific part of the project where we put the variance modifier on the type argument. In the example code above, it only works for the **`getSnackFrom()`** function. So, if other functions in our project still need to use the **`refund()`** function, that's completely fine. In those places, **`VendingMachine<CandyBar>`** simply wouldn't be able to be a subtype of **`VendingMachine<Snack>`**.

## Out-Projections

It's important to note that, within the body of this function, **`machine`** does *not* have the type **`VendingMachine<Snack>`**. It has the type **`VendingMachine<out Snack>`**, which is a **type projection**. Since this type argument has the **`out`** modifier on it, this particular kind of type projection is called an **out-projection**.

What exactly is a projection?



Think of a projection like a shadow. If you shine a light on a ball, it casts a shadow onto the wall. The ball itself is a sphere that has three dimensions, but the ball's shadow on the wall is a circle that has only two dimensions. The shadow still *resembles* the ball, but it's missing its depth.[1]

Similarly, when we create a type projection, it's kind of like we're removing some of the "depth" of that object by limiting the types of its function inputs and outputs.

For example, in the **`getSnackFrom()`** function above, we created a type projection from **`VendingMachine<Snack>`**, called **`VendingMachine<out Snack>`**, which looks a lot like the original, except that the **`refund()`** function no longer accepts a **`Snack`**. Instead, it accepts a type called **`Nothing`**!

[1] The word "projection" in the term "type projection" is technically rooted in mathematics, but the idea is the same.

Original Generic Class

```
class VendingMachine<T : Product>(...) {
    fun purchase(money: Money): T = ...
    fun refund(product: T): Money = ...
}
```

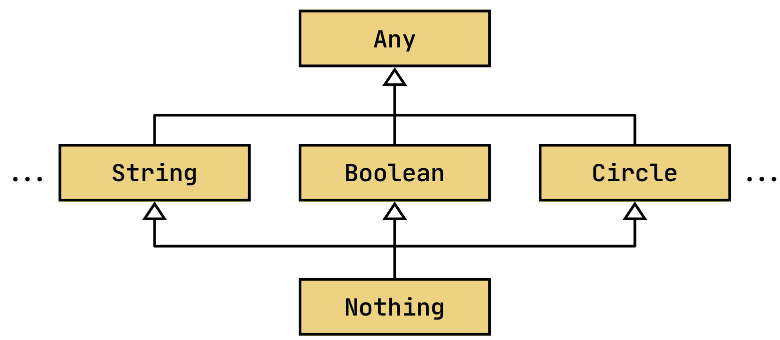
Effective Parameterized Type

```
class VendingMachine<Snack>(...) {
    fun purchase(money: Money): Snack = ...
    fun refund(product: Snack): Money = ...
}
```

Effective Out-Projected Type

```
class VendingMachine<out Snack>(...) {
    fun purchase(money: Money): Snack = ...
    fun refund(product: Nothing): Money = ...
}
```

What exactly is **`Nothing`**? As mentioned in Chapter 14, every type in Kotlin is a *subtype* of a class named **`Any`**. Similarly, every type in Kotlin is also a *supertype* of a class called **`Nothing`**.




The **`Nothing`** class can never be instantiated, because it only has a **`private`** constructor. Since it's impossible to create an instance of **`Nothing`**, we'll never be able to call **`refund()`** here in this function.

## By the Way: Nothing

The **`Nothing`** type sounds useless, but besides being helpful for type projections, you can also use it as a return type for a function that will never return—that is, a function that will always throw an exception.

It's also interesting to note that in Kotlin, **`null`** has a type, and that type is **`Nothing?`**.

So, an out-projection is created by adding the **`out`** modifier to a type argument. It looks similar to the original parameterized type, but everywhere that the type argument appears in an in-position, it is replaced with the **`Nothing`** type.

## In-Projections

As you can probably guess, we can also use an `in` modifier to create an **in-projection**, like in this function.

```
fun getRefundFrom(machine: VendingMachine<in CandyBar>): Money {
    return machine.refund(CandyBar())
}
```

*Listing 19.31 - A function with a parameter whose type is an in-projection.*

As with the out-projection above, inside the body of this function, we end up with a projection of `VendingMachine<CandyBar>`. But this time, instead of affecting the functions' *parameter* types, it's the functions' *result* types that have been affected.

With an in-projection, everywhere that the type argument appears in an out-position, it is forced to `Any?`.

It's entirely possible to call these functions and get a result. If we want to do anything useful with that result, though, we'll probably need to cast it back to its more specific type.

Original Generic Class

```
class VendingMachine<T : Product>(...) {
    fun purchase(money: Money): T = ...
    fun refund(product: T): Money = ...
}
```

Effective Parameterized Type

```
class VendingMachine<Snack>(...) {
    fun purchase(money: Money): Snack = ...
    fun refund(product: Snack): Money = ...
}
```

Effective In-Projected Type

```
class VendingMachine<in Snack>(...) {
    fun purchase(money: Money): Any? = ...
    fun refund(product: Snack): Money = ...
}
```

So, out-projections and in-projections are two kinds of type projections.

- An out-projection creates *covariance* by forcing the type argument in in-positions to `Nothing`.
- An in-projection creates *contravariance* by forcing the type argument in out-positions to `Any?`.

Sometimes we want a function to accept all instances of a generic type, regardless of their type arguments. For these cases, Kotlin includes one more kind of projection.

## Star-Projections

Remember Vinnie? Well, at the end of the month, he services all of his vending machines, performing basic maintenance in order to keep them finely-tuned and working well. This operation doesn't involve any money, snacks, or toys. He just needs to get in there and tighten a few bolts.

Here's an updated version of **`VendingMachine`** that includes a function named **`tune()`**. As you can see, this new function doesn't use a type parameter at all—neither as a function parameter nor as a return type.

```
class VendingMachine<T : Snack>(private val snack: T) {
    fun purchase(money: Coin): T = snack
    fun refund(snack: T): Coin = Dime()
    fun tune() = println("All tuned up!")
}
```

*Listing 19.32 - Adding a function that does not use the type parameter.*

All vending machines need to be tuned up. The type of the **`Snack`** that they return is completely irrelevant.

In cases like these, we might want a function to accept literally any kind of type created from **`VendingMachine`**. Kotlin makes this easy with a special kind of type projection called a **star-projection**. To create a star-projection, rather than using a variance modifier, simply use an asterisk `*` (that is, a "star") in place of the type argument. For example, here's a function that will accept any kind of **`VendingMachine`**, regardless of its type argument.

```
fun service(machine: VendingMachine<*>) {
    print("Tuning up $machine... ")
    machine.tune()
}
```

*Listing 19.33 - A function with a parameter whose type is a star-projection.*

This function can be called with any kind of **`VendingMachine`**, regardless of its type argument.

```
service(VendingMachine(CandyBar()))   // Works with VendingMachine<CandyBar>
service(VendingMachine(TrailMix()))   // Works with VendingMachine<TrailMix>
service(VendingMachine(GummyBears())) // Works with VendingMachine<GummyBears>
```

*Listing 19.34 - Calling the* **`service()`** *function with different kinds of vending machines.*

A star-projection looks similar to the original parameterized type, but it changes it in these ways.

- Anywhere that the type parameter was used in an *in-position*, it'll be replaced with the **`Nothing`** type.
- Anywhere that the type parameter was used in an *out-position*, it'll be replaced with the type parameter's upper bound. Remember—if no upper bound was specified, it'll be **`Any?`** by default.

Original Generic Class

```
class VendingMachine<T : Product>(...) {
    fun purchase(money: Money): T = ...
    fun refund(product: T): Money = ...
}
```

Effective Parameterized Type

```
class VendingMachine<Snack>(...) {
    fun purchase(money: Money): Snack = ...
    fun refund(product: Snack): Money = ...
}
```

Effective Star-Projected Type

```
class VendingMachine<*>(...) {
    fun purchase(money: Money): Product = ...
    fun refund(product: Nothing): Money = ...
}
```

In summary, star-projections are useful when we want to accept any instance of a generic type, regardless of its type arguments.

## Variance in the Standard Library

Now that we've learned all about covariance, contravariance, variance modifiers, and type projections, we can better understand why certain types in the standard library work the way that they do.

We opened this chapter by presenting the fact that `MutableList<Cow>` is a subtype of `List<Cow>`, but it's not a subtype of `MutableList<FarmAnimal>`. Why is this?

- `MutableList<Cow>` is a subtype of `List<Cow>` because `MutableList` extends the `List` interface. That's just regular interface inheritance.
- `MutableList<Cow>` is *not* a subtype of `MutableList<FarmAnimal>` because it allows you to both read *and* modify its elements, which means its type parameter appears in both the in-position *and* out-position. As a result, it can't have a variance modifier on it. This is similar to our `VendingMachine` in Listing 19.26.

As we've seen, the collection types in Kotlin usually come in two flavors—a read-only type (e.g., `List`) and a mutable type (e.g., `MutableList`).

- The read-only types will have the `out` modifier on their type parameters, so `List<Cow>` will be a subtype of `List<FarmAnimal>`.
- However, the mutable types *won't* have any variance modifiers, so `MutableList<Cow>` will *not* be a subtype of `MutableList<FarmAnimal>`.

As you now know, though, you can use a type projection to work around this when it makes sense!

# Summary

Now that Parker and Vinnie understand which vending machines honor the contract, they can confidently replace them without making any parents angry or kids hungry. And now that you understand how generics form subtypes, you can confidently use variance without breaking your code!

Congratulations on working your way through this chapter! Here's a recap of what we covered:

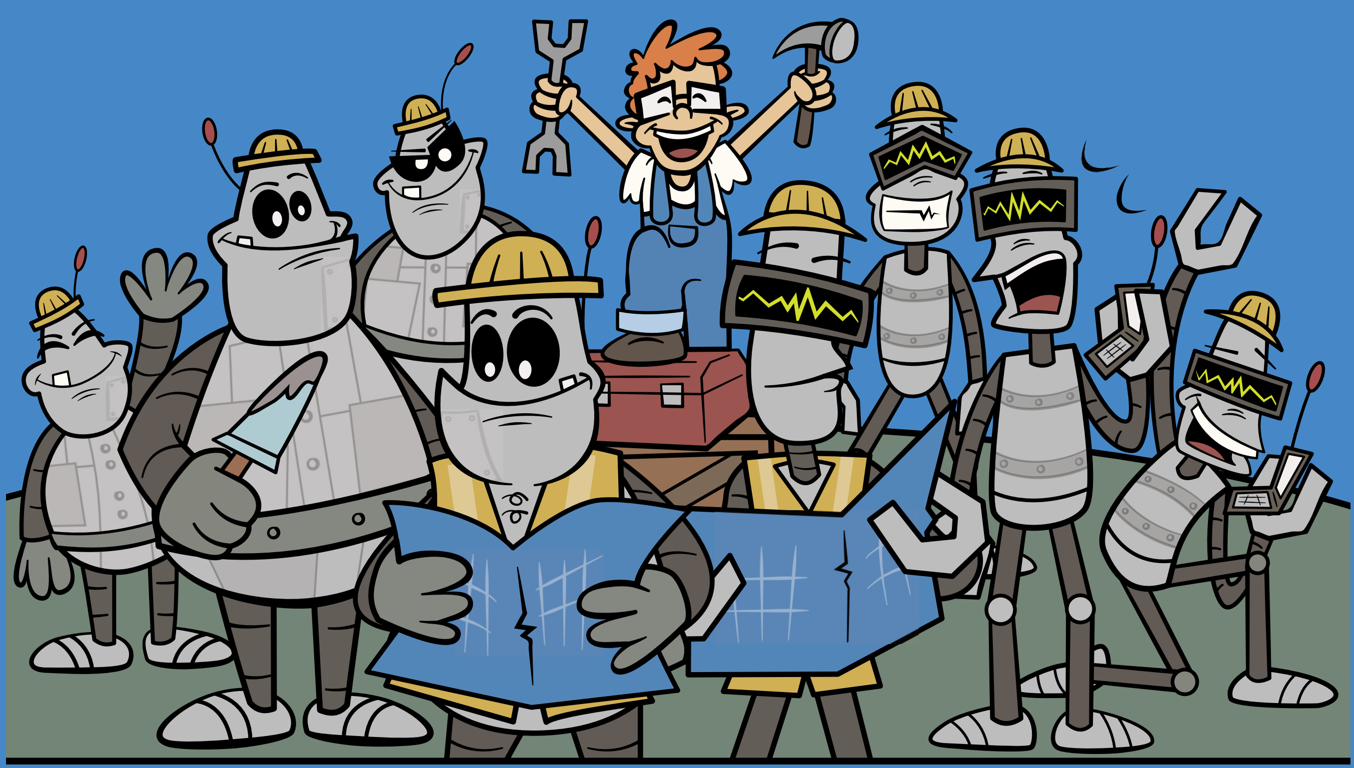
- How covariance describes the relationship between a type and its function *return types*.
- How contravariance describes the relationship between a type and its function *parameter types*.
- How we can use variance modifiers on *type parameters* to create declaration-site variance.
- How we can use variance modifiers on *type arguments* to create use-site variance.
- How collection types in the standard library use variance modifiers.

You've come a long way since the first chapter—starting with the basics of variables and expressions, building up to generics and variance. Now, for our final chapter, we'll explore one of Kotlin's most exciting topics—*coroutines!*

Kotlin: An Illustrated Guide

Chapter 20

# Coroutine Essentials



## Sometimes it's helpful to do more than one thing at a time!

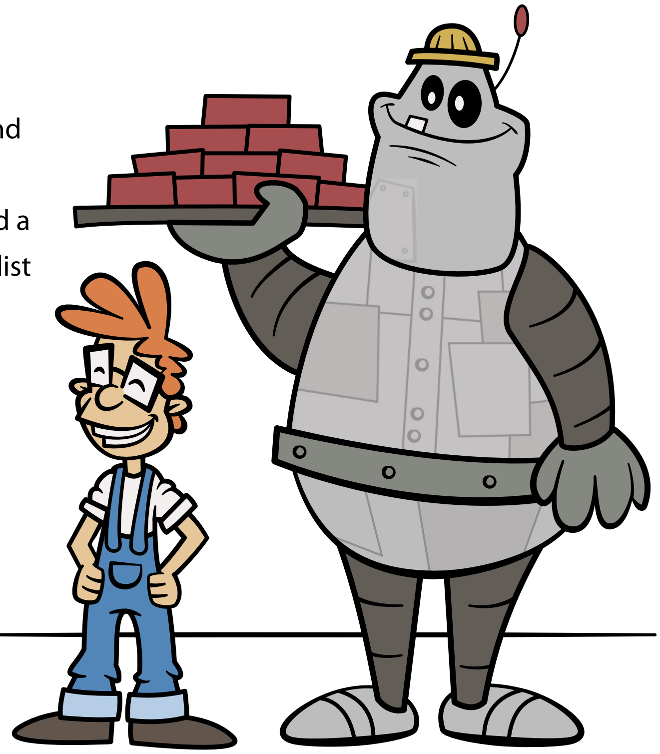
When you're on hold during a phone call, you might also check your email. While brewing coffee, you might also cook breakfast. And while driving a car, you might listen to a podcast.

In the same way, sometimes it's helpful for the software that we write to do more than one thing at a time. For example, it could make two or three network calls at one time—all while updating the screen to show the progress of each call.

In Kotlin, we can use coroutines to do multiple things at a time. There are many ways to use coroutines. In fact, it'd be easy to dedicate an entire book to exploring them. In this chapter, we're going to focus on the most essential coroutine concepts you need to be productive with them in your day-to-day coding. This knowledge will give you the confidence to start using them in your applications, and it'll provide a solid foundation for understanding more advanced coroutine concepts in the future, if you choose to explore them further.

Let's begin our adventure with coroutines by visiting Rusty and his trusty robot, Bot-1.

# One Thing at a Time...

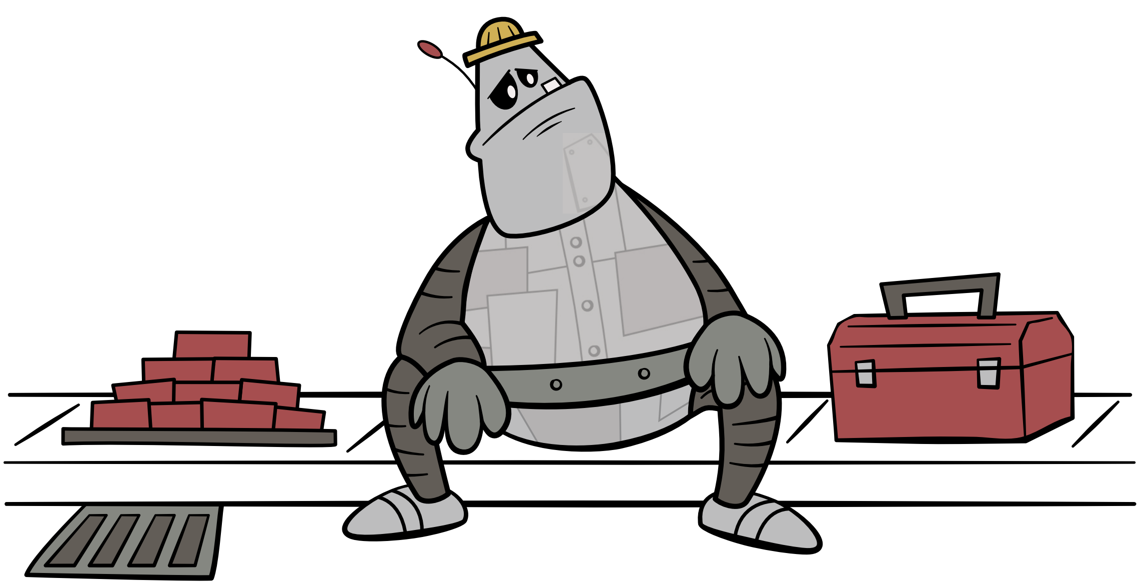


Rusty McAnnick spends most of his days engineering and managing Bot-1, his heavy-duty robot who works on construction projects. One day, Rusty and Bot-1 received a work order for constructing a new building. Their checklist for this project included three tasks:

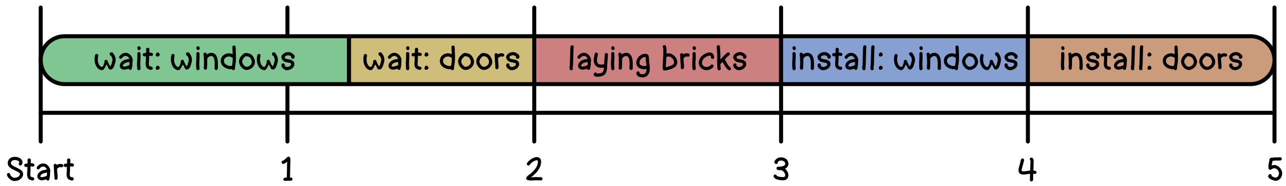
- Lay the bricks for the foundation.
- Install the doors.
- Install the windows.

Rusty and Bot-1 have a large pile of bricks on hand, but the windows and doors are ordered specifically for each project, so they have to be delivered from the warehouses. They arrived at the construction site, ready to get started. Here's how the day went.

1. Bot-1 called a warehouse to order the windows needed for this project. The delivery took a while to arrive. While he was waiting, he sat on the curb, twiddling his thumbs. Once the truck finally showed up, he got the windows off of the truck.
2. Next, he called a different warehouse to order the doors. Again, he sat down on the curb, bored, waiting for the doors to be delivered. When they finally arrived, he unloaded them.
3. Next, he laid the bricks. This part required some time and effort, but he completed the job skillfully.
4. Then, he installed the windows.
5. Finally, he installed the doors.



If we lay out the work that Bot-1 did over time, here's what the timeline would look like.




Once the project was complete, Rusty took inventory of all the tasks, and shook his head. "That project took a really long time. Those deliveries were so slow. And the client wasn't happy that we took so long to finish the project. I wonder… what can we do to speed things up?"

## Single-Threaded, Blocking Code

Just like Rusty's construction project, our Kotlin code can be inefficient when we do only one thing at a time, especially when it involves waiting for slow operations, like network requests. To start with, let's create an enum class to represent the products that can be ordered from a warehouse, and a function to place an order.

```
enum class Product(val description: String, val deliveryTime: Long) {
    DOORS("doors", 750),
    WINDOWS("windows", 1_250)
}

fun order(item: Product): Product {
    println("ORDER EN ROUTE  >>> The ${item.description} are on the way!")
    Thread.sleep(item.deliveryTime)
    println("ORDER DELIVERED >>> Your ${item.description} have arrived.")
    return item
}
```

*Listing 20.1 - An enum class representing products, along with a function that simulates ordering a product.*

In the code above, we're using `Thread.sleep()` to simulate the amount of time that it takes for the truck to deliver the product. Since each product is at a different warehouse, they have different delivery times. `Thread.sleep()` takes a `Long` argument that indicates how long to pause, in milliseconds—so to wait one second, we can pass `1_000`.

### By the Way: Underscores in Numbers

In Kotlin, we're allowed to insert underscores within our number literals. They can't go at the beginning or end, but anywhere in the middle is fair game. Frequently they're used to group the digits as we might normally do with a comma or a decimal point. For example, we could use `1_000_000` for one million, or `10_00` to represent ten dollars in cents.

Next, let's do the same thing for the tasks that Bot-1 needs to perform.

```
fun perform(taskName: String) {
    println("STARTING TASK   >>> $taskName")
    Thread.sleep(1_000)
    println("FINISHED TASK   >>> $taskName")
}
```

*Listing 20.2 - A function that simulates performing some task.*

With these functions in place, we can model Rusty's recent project like this.

```
fun main() {
    val windows = order("windows")
    val doors = order("doors")
    perform("laying bricks")
    perform("installing $windows")
    perform("installing $doors")
}
```

*Listing 20.3 - Modeling Rusty's project by calling the* `order()` *and* `perform()` *functions.*

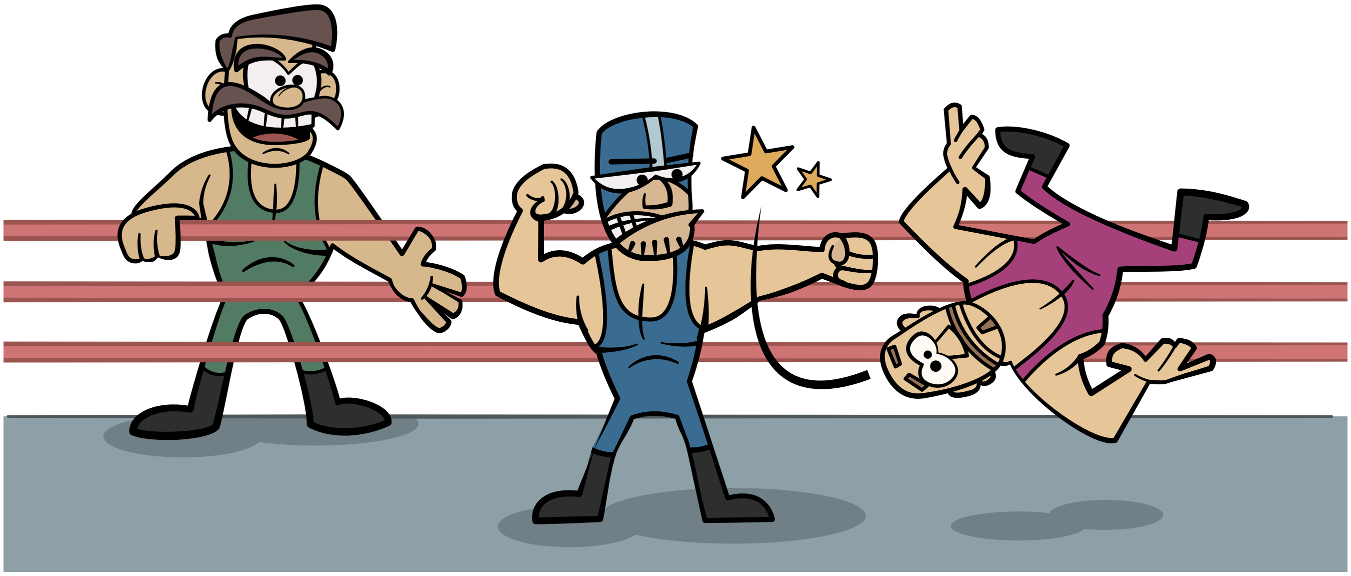
When we run this code, we'll see output that looks like this.

```
ORDER EN ROUTE  >>> The windows are on the way!
ORDER DELIVERED >>> Your windows have arrived.
ORDER EN ROUTE  >>> The doors are on the way!
ORDER DELIVERED >>> Your doors have arrived.
STARTING TASK   >>> laying bricks
FINISHED TASK   >>> laying bricks
STARTING TASK   >>> installing windows
FINISHED TASK   >>> installing windows
STARTING TASK   >>> installing doors
FINISHED TASK   >>> installing doors
```

Just like with Rusty's construction work, this code is a very slow way to get the job done. Let's see what ideas Rusty comes up with to make his work more efficient!

# Coroutines and Concurrency

Later that night, Rusty sat on his comfortable couch, flipping through channels on the television. He finally settled on a channel featuring professional tag-team wrestling. This tag-team wrestling match involved two teams of wrestlers, each with two teammates, where only one wrestler from each team can be in the ring at a time. By tagging his teammate who is waiting outside of the ring, the two wrestlers can switch places.



Rusty watched with excitement, rooting for the team of Sledge and Hammer as they took on the current champions, Villain and Vandal.

Here's what happened as he watched.

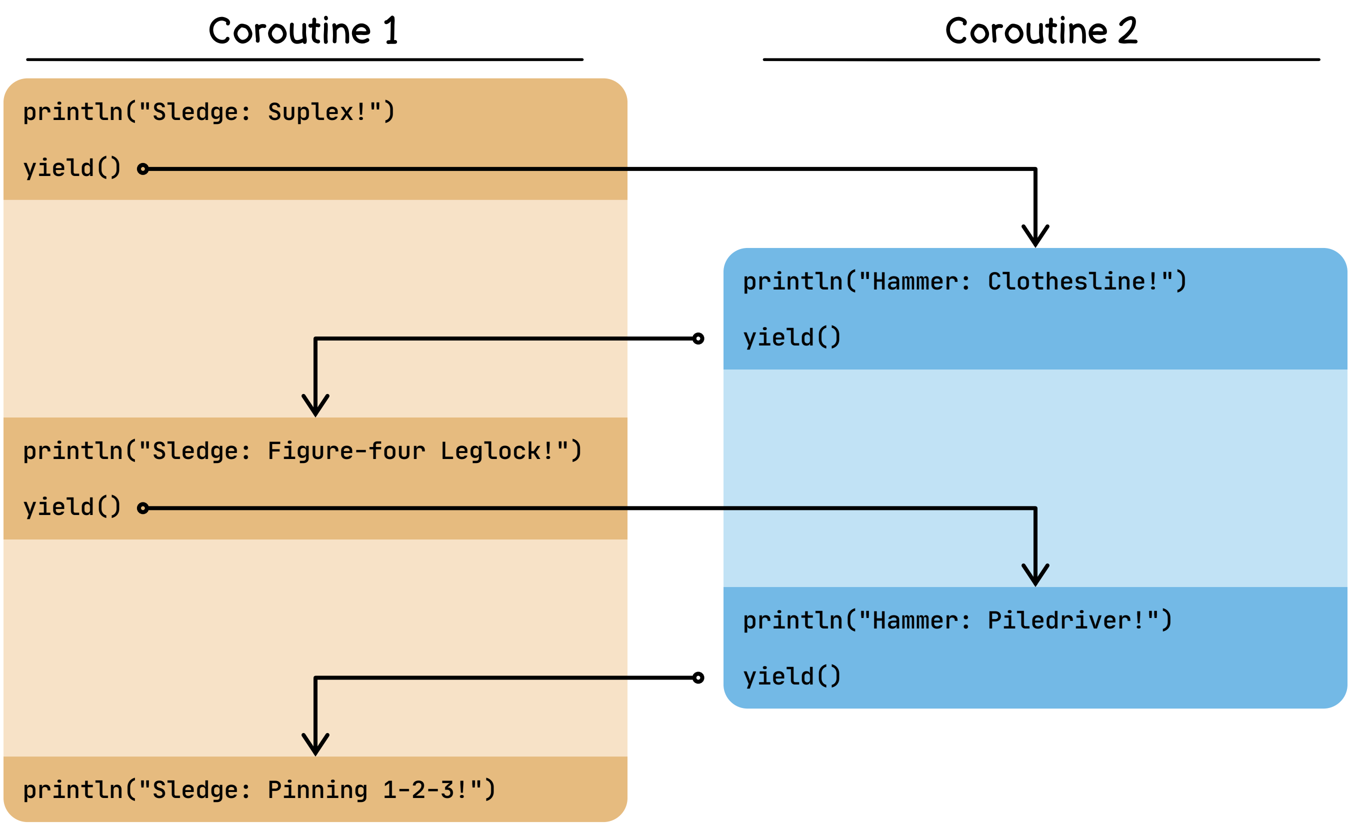
1. *Sledge* took his turn in the ring, suplexing Vandal. Then, he tagged Hammer, and the two teammates switched places.
2. Next, *Hammer* entered the ring, using a clothesline move to knock Vandal to the floor. Then he tagged Sledge, and they switched places again.
3. *Sledge* returned to the ring and put Vandal into a figure-four leglock. He tagged Hammer again, and they changed places.
4. *Hammer* stepped back into the ring, and used a piledriver on Vandal. He tagged Sledge one more time.
5. Finally, *Sledge* entered the ring again and pinned Vandal to the mat for three seconds, winning the match!

While Rusty keeps watching the wrestling event, let's get back to some Kotlin code.

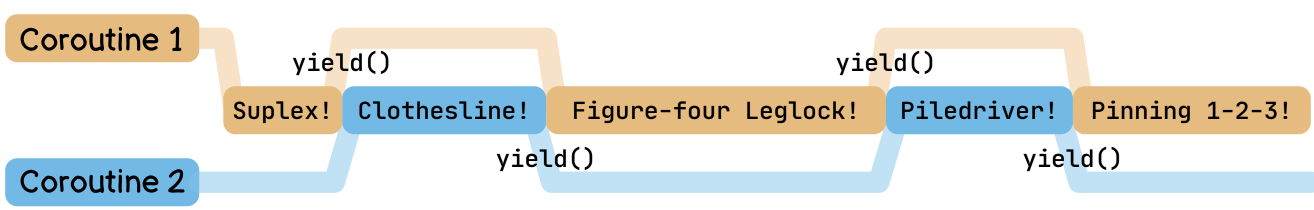
## Introduction to Coroutines

Code written with coroutines works a lot like tag-team wrestling—one coroutine can do some work, then tag out and let another coroutine run for a while.

By tagging in and tagging out, the execution path alternates between the coroutines, as shown in the illustration on the next page.




The code above demonstrates the essence of coroutines, which is that the execution path can *bounce back and forth* between parts of different functions. When code is written this way, we say that the tasks run **concurrently**.




## By the Way: The Coroutines Library

You'll need to add a dependency on the `kotlinx.coroutines` library for the rest of the code in this chapter. The way you do this differs depending on your build tool. See the instructions in Appendix B for Gradle and Maven.

Ready to create our first coroutine? We can build a new coroutine by calling a special kind of function known as a **coroutine builder**. Our very first coroutine builder is named `runBlocking()`. This function takes a lambda, which contains the code that this coroutine will run. (And be sure to include `import kotlinx.coroutines.runBlocking` in the file where you're writing the code!)

```
import kotlinx.coroutines.runBlocking

fun main() {       coroutine builder
    runBlocking {
        println("Sledge: Suplex!")
        println("Hammer: Clothesline!")
        println("Sledge: Figure-four Leglock!")    suspending function body
        println("Hammer: Piledriver!")
        println("Sledge: Pinning 1-2-3!")
    }
}
```

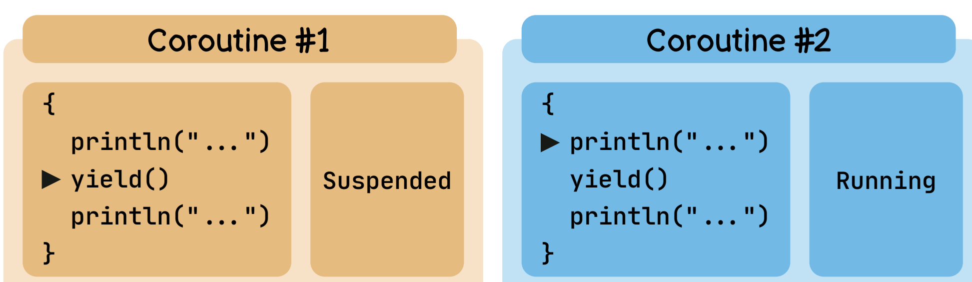
*Listing 20.4 - Our first coroutine!*

Let's look more closely at each part of this code.

- **`runBlocking()`** is a function that creates (and usually starts) a coroutine. As mentioned above, this kind of function is called a *coroutine builder*.
- The lambda passed to **`runBlocking()`** is a special kind of function called a **suspending function**. Like a tag-team wrestler, a suspending function can "tag out" the coroutine, allowing another coroutine to run in the meantime. Instead of saying that it "tags out," we say that it **suspends** execution. Since this suspending function is written as a lambda, this one can also be referred to as a *suspending lambda*.
- This suspending function runs inside a *coroutine*. The coroutine can be suspended by the suspending function.

## Where's the Coroutine?

When we look at the code, we can point to the *coroutine builder*, and we can point to the *suspending function*. But oddly, we can't point to the actual coroutine itself. That's because a coroutine is an *instance* of a block of code, along with some configuration and information about its state—such as whether it's currently running, paused, completed, and so on.




Have you ever run the same Kotlin project in more than one IDE at the same time? Or have you run it from the command line in more than one console window at the same time?

When you do this, each execution of the program is its own *instance*. It has its own state.

For example, if you create a program to count to one million, you could run the same program twice at the same time, and at any given moment, each instance would be on a different number from the other.

Console #1

```
> java -jar count.jar

1
2
3
4
5
6
7
8
```

Console #2

```
> java -jar count.jar

1
2
3
```

In a similar way, a coroutine is an *instance of execution*, with its own state. But instead of executing an *entire program*, it's executing the block of code that was passed to its coroutine builder. And instead of its execution being managed by machinery within *operating system*, it's managed by machinery within our *Kotlin program*.

## Let's Start Suspending!

Now, the code in Listing 20.4 includes a suspending function, which *can* suspend, but so far, it's not *actually* suspending. All it's doing is printing lines to the console. We could have done that *without* **`runBlocking()`**! We also have only a *single* coroutine, which is like a single wrestler instead of a team.

Let's create a *second* coroutine that can work together with the first. To do this, we can call a coroutine builder from *within* the **`runBlocking()`** lambda.

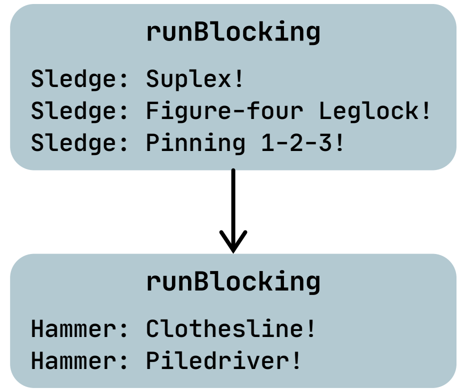
Since **`runBlocking()`** is the only coroutine builder we've used so far, let's try using it again here. We'll put the second and fourth wrestling moves in the *nested* coroutine builder, and the first, third, and fifth in the outer lambda, with the intention that the wrestling moves will alternate between the coroutines like they did with the wrestlers, Sledge and Hammer.

```kotlin
import kotlinx.coroutines.runBlocking

fun main() {
    runBlocking {
        runBlocking {
            println("Hammer: Clothesline!")
            println("Hammer: Piledriver!")
        }
        println("Sledge: Suplex!")
        println("Sledge: Figure-four Leglock!")
        println("Sledge: Pinning 1-2-3!")
    }
}
```

*Listing 20.5 - Nesting one coroutine within another.*

Since we've got one **`runBlocking()`** function call inside the lambda of another, we're *creating a coroutine from within another coroutine.*

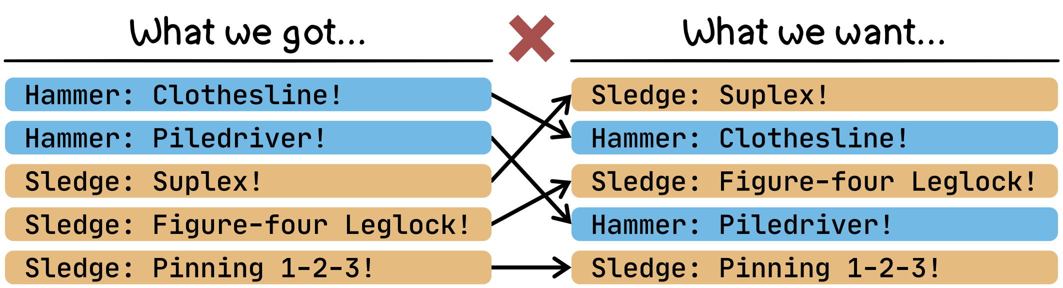
This creates a parent-child relationship between the two coroutines, resulting in a simple hierarchy structure that looks like the diagram to the right.




Later in this chapter, we'll see why this structure is important. Meanwhile, when we run the code above, we'll get output that looks like this.

```
Hammer: Clothesline!
Hammer: Piledriver!
Sledge: Suplex!
Sledge: Figure-four Leglock!
Sledge: Pinning 1-2-3!
```

Hmm… this prints all of the wrestling moves, but they're not in the order that we wanted! The moves are printed in the same order that they appear in the code. It's like the first wrestler did *all* of his moves, and then the second wrestler did all of *his* moves.




One problem here is that the **`runBlocking()`** coroutine builder *waits until its code finishes* before moving on. So, the code in the nested **`runBlocking()`** lambda runs until it's done (printing "Clothesline!" and "Piledriver!"), and then the rest of the **`println()`** statements in the outer lambda run.

Since **`runBlocking()`** waits until its coroutine completes before moving on, it's typically only used to build a root-level coroutine. In other words, it's frequently only used directly in the **`main()`** function. From there, other coroutines are usually built with *other* coroutine builders.

It's time to introduce our second coroutine builder, named **`launch()`**. Like **`runBlocking()`**, the **`launch()`** function also accepts a suspending lambda as an argument. Let's replace the nested **`runBlocking()`** call with a call to **`launch()`**.

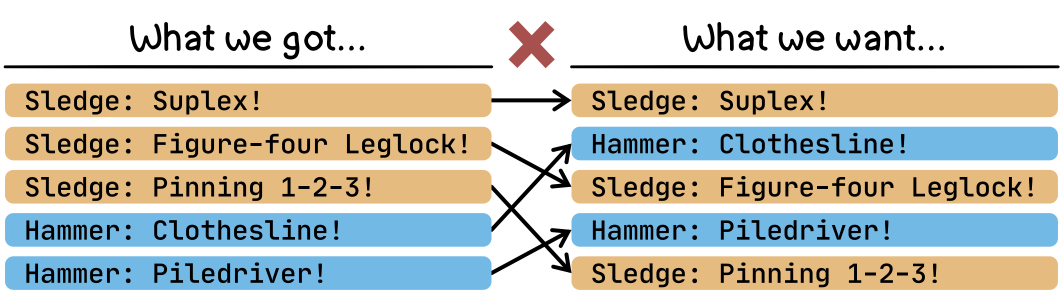
Be sure to include the import for **`kotlinx.coroutines.launch`**.

```
import kotlinx.coroutines.launch
import kotlinx.coroutines.runBlocking

fun main() {
    runBlocking {
        launch {
            println("Hammer: Clothesline!")
            println("Hammer: Piledriver!")
        }
        println("Sledge: Suplex!")
        println("Sledge: Figure-four Leglock!")
        println("Sledge: Pinning 1-2-3!")
    }
}
```

*Listing 20.6 - Using the* `launch()` *coroutine builder.*

```
Sledge: Suplex!
Sledge: Figure-four Leglock!
Sledge: Pinning 1-2-3!
Hammer: Clothesline!
Hammer: Piledriver!
```

Well… that's still not right! The result is almost the same as that of Listing 20.5, except that the wrestlers traded places. Last time, all the wrestling moves from the *inner* lambda were printed first. This time, all the wrestling moves from the *outer* lambda were printed first. In fact, with this output, their opponent was pinned in the *middle* of the match!




The problem is that our wrestlers aren't tagging out after each move, so they never yield the ring to the other wrestler. In Kotlin if we want a coroutine to tag out, it has to encounter a **suspension point**. Generally speaking, this happens when it calls a suspending function.[1]

[1] Many Kotlin developers find it a helpful generalization to think of a suspension point as any call to a suspending function, but that's not entirely precise. It's possible to write a suspending function that doesn't actually suspend. Down in the lowest depths of the coroutine machinery, there's a function named `suspendCoroutineUninterceptedOrReturn()`. A suspension point technically occurs when this function is called with a lambda that returns a special value called `COROUTINE_SUSPENDED`. When functions like `delay()` or `yield()` are called, they might call another function or two, but somewhere inside the call stack, it will result in a call to `suspendCoroutineUninterceptedOrReturn()`, which is the actual suspension point.

To demonstrate this, let's update our code so that after each move, we include a call to a function named **`yield()`**.

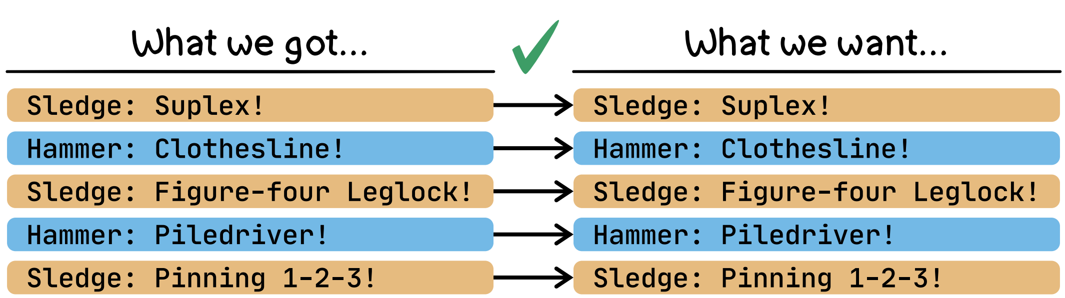
```
import kotlinx.coroutines.launch
import kotlinx.coroutines.runBlocking
import kotlinx.coroutines.yield

fun main() {
    runBlocking {
        launch {
            println("Hammer: Clothesline!")
            yield()
            println("Hammer: Piledriver!")
            yield()
        }
        println("Sledge: Suplex!")
        yield()
        println("Sledge: Figure-four Leglock!")
        yield()
        println("Sledge: Pinning 1-2-3!")
    }
}
```

*Listing 20.7 - Yielding the coroutine after each call to* **`println()`**.

**`yield()`** is a suspending function, and each time we call it, the coroutine hits a suspension point. This yields the wrestling ring back to the wrestler's teammate—in other words, it gives the *other* coroutine a chance to run some of its code.

So, the execution path bounces back and forth between the **`runBlocking()`** lambda and the **`launch()`** lambda. The resulting output shows the wrestling moves in the correct order.

```
Sledge: Suplex!
Hammer: Clothesline!
Sledge: Figure-four Leglock!
Hammer: Piledriver!
Sledge: Pinning 1-2-3!
```



## Declaring a Suspending Function

Let's update our code so that the output shows each time that a wrestler is tagging out. So instead of directly calling **`yield()`**, we could create another function that prints "Tagging out!" and *then* calls **`yield()`**.

If we try to declare a regular function for this, we'll get a compiler error.

```
fun tagOut() {
    println("    Tagging out!    ")
    yield()
}
```

*Listing 20.8 - **Error:** Suspend function **`yield`** should only be called from a coroutine or another suspend function.*

The reason for this error is that a suspending function can't be called from just anywhere. It can only be called from *another* suspending function! In other words, a regular function can call a regular function, and a suspending function can call either a regular function or another suspending function.

| | …a regular function? | …a suspending function? |
|---|---|---|
| Can a regular function call… | Yes | No |
| Can a suspending function call… | Yes | Yes |

To fix this error, we can simply add the **`suspend`** modifier to this function.

```
suspend fun tagOut() {
    println("    Tagging out!    ")
    yield()
}
```

*Listing 20.9 - Our first suspending function!*

By doing this, we've changed the **`tagOut()`** function from a regular function to a suspending function, so it's now possible for it to call **`yield()`**.

### By the Way: "Suspend Function"

Since the modifier is named **`suspend`**, many Kotlin developers simply refer to this kind of function as a "suspend function" instead of "suspending function"—but they both mean the same thing. It would be most precise to say "a function that is capable of suspending a coroutine," but that's quite a mouthful!

Instead, throughout the rest of this chapter, we'll use the term "suspending function".

Now that we've created the **`tagOut()`** function, we can go back to our **`main()`** function and replace the call to **`yield()`** with a call to **`tagOut()`**.

```
fun main() {
    runBlocking {
        launch {
            println("Hammer: Clothesline!")
            tagOut()
            println("Hammer: Piledriver!")
            tagOut()
        }
        println("Sledge: Suplex!")
        tagOut()
        println("Sledge: Figure-four Leglock!")
        tagOut()
        println("Sledge: Pinning 1-2-3!")
    }
}
```

*Listing 20.10 - Calling* **`tagOut()`** *instead of directly calling* **`yield()`**.

When we run this, the output looks like this.

```
Sledge: Suplex!
    Tagging out!
Hammer: Clothesline!
    Tagging out!
Sledge: Figure-four Leglock!
    Tagging out!
Hammer: Piledriver!
    Tagging out!
Sledge: Pinning 1-2-3!
```

So, we can write our own suspending functions that call *other* suspending functions, like **`yield()`**. Often the suspending functions that we write in our own application's code will simply call other suspending functions, usually from a library. For example, we could use the Ktor HTTP client library to make an HTTP call, which would suspend the coroutine until a response is received.

```
suspend fun getExample(): String {
    return client.get("https://www.example.com/").bodyAsText()
}
```

*Listing 20.11 - A suspending function that calls another suspending function, named* **`get()`**, *in the Ktor library,.*

Before we move on, let's review the main concepts we've learned in this section:

- Coroutines can run *concurrently* with one another. In other words, their execution can be suspended in order to give other coroutines a chance to run.

- *Suspending functions* are able to suspend the coroutines that run them. They can only be called from other suspending functions.
- The `runBlocking()` builder creates a coroutine. Any code that comes after `runBlocking()` won't run until its coroutine has finished running.
- The `launch()` builder also creates a coroutine, and any code that comes after it will be run right after the coroutine is launched.

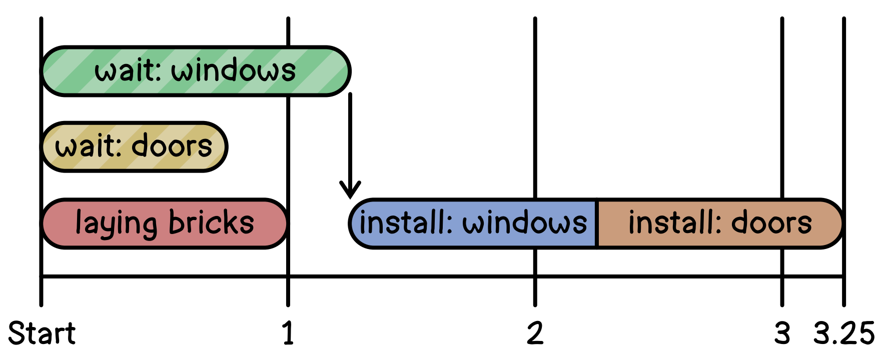
It's been fun considering the similarities between coroutines and tag-team wrestlers, but Rusty has some big projects coming up, and he needs to find more efficient ways to finish his projects. So let's see what he's up to!

# Two Things at a Time…

After watching the rest of the wrestling event, Rusty went to bed. As he tried to fall asleep, he wondered how he could make his construction projects more efficient. He thought, "What if our tasks could be more like tag-team wrestlers? What if Bot-1 could get started on one task, and then that task could "tag out" and let Bot-1 work on another task for a while… and then that task could also be paused, and Bot-1 could return to the first task…?"

The next day, he decided to test it out. He received a work order to construct another building. "This time," he said, "whenever we order the supplies, instead of just waiting for the delivery, let's start working on the next available task." So, Bot-1 got to work. Here's how the day went.

1. First he called the warehouse to order the windows.
2. Without waiting for them, he immediately called the other warehouse to order the doors.
3. Then, he got to work on the bricks right away. While he was still working on the bricks, the delivery truck dropped off the doors. Soon after he laid the last brick, the second truck arrived and dropped off the windows.
4. Bot-1 installed the windows.
5. Finally, he installed the doors.



Rusty was much happier after this project was completed. By doing some work, putting it down, working on something else, and eventually coming back to the first thing, they were able to save lots of time. Bot-1 spent much less time sitting on the curb!

## Modeling the Construction Site

Now that we've been introduced to the concepts of coroutines, coroutine builders, suspending functions, and suspension points, let's bring our knowledge back to Rusty and Bot-1. Back in Listing 20.2, we introduced a function to order supplies such as windows and doors. Let's convert it to a suspending function, and replace **`Thread.sleep()`** with a suspending function from the coroutines library, named **`delay()`**.

```
import kotlinx.coroutines.delay

suspend fun order(item: Product): Product {
    println("ORDER EN ROUTE  >>> The ${item.description} are on the way!")
    delay(item.deliveryTime)
    println("ORDER DELIVERED >>> Your ${item.description} have arrived.")
    return item
}
```

*Listing 20.12 - Updating* **`order()`** *so that it is a suspending function that calls another suspending function—named* **`delay()`**.

Just like with **`Thread.sleep()`**, the **`delay()`** function accepts a **`Long`** argument that tells it how long to delay. So what are the differences between **`Thread.sleep()`** and **`delay()`**?

- **`Thread.sleep()`** does *not* suspend a coroutine. Instead, it simply blocks the execution for the designated amount of time. Since it doesn't suspend, it doesn't give another coroutine a chance to run in the meantime. This function can be called from either a regular function or a suspending function.
- **`delay()`** *does* suspend the coroutine. This means the coroutine can set down its work for the designated amount of time, allowing some other coroutine to run in the meantime. This function can only be called from within a suspending function.

### By the Way: What About `perform()`?

Back in Listing 20.2, we added a second function, named **`perform()`**. Both **`order()`** and **`perform()`** included a call to **`Thread.sleep()`**. Although we updated **`order()`** to use **`delay()`**, we did not update **`perform()`** to do the same. Why not?

- The **`order()`** function represents *requesting an external resource*—like loading a file from the file system or requesting a JSON document from a REST service.
- The **`perform()`** function, on the other hand, represents *work that keeps the CPU busy*, such as transforming large data sets or running complex calculations.

Input/output operations (like the one simulated by `order()`) can happen in the background, without blocking execution. Then, once the operation is finished, our code can continue with the result. So, these operations are best simulated with a suspending function like `delay()`.

CPU-heavy operations, however, *keep the processor busy* with whatever it's calculating, blocking other work from happening. So, these operations are best simulated with a blocking operation like `Thread.sleep()` (…although if you're feeling inspired, you could give your `perform()` function some busy-work instead, such as figuring out some quantity of prime numbers).

Just like with regular functions, suspending functions can return a value, as the two functions above are doing. There are many Kotlin libraries that use suspending functions to return something important. For example, the Ktor client library mentioned earlier includes suspending functions that return a response from a Web service.

Naturally, we can also assign the result to a variable. To try this out, let's take our code from Listing 20.3, and put it inside a `runBlocking()` lambda.

```
fun main() {
    runBlocking {
        val windows = order(Product.WINDOWS)
        val doors = order(Product.DOORS)
        perform("laying bricks")
        perform("installing ${windows.description}")
        perform("installing ${doors.description}")
    }
}
```

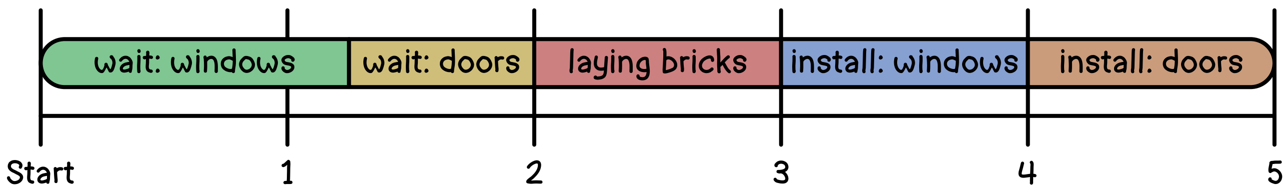
*Listing 20.13 - Assigning the result of a suspending function.*

Even though this code runs in a coroutine, and even though the `order()` function is now a suspending function, we still get the exact same output as we had in Listing 20.3.

```
ORDER EN ROUTE  >>> The windows are on the way!
ORDER DELIVERED >>> Your windows have arrived.
ORDER EN ROUTE  >>> The doors are on the way!
ORDER DELIVERED >>> Your doors have arrived.
STARTING TASK   >>> laying bricks
FINISHED TASK   >>> laying bricks
STARTING TASK   >>> installing windows
FINISHED TASK   >>> installing windows
STARTING TASK   >>> installing doors
FINISHED TASK   >>> installing doors
```

This demonstrates that the code in a coroutine still runs top-to-bottom, just like regular Kotlin code—and this is true even when calling suspending functions instead of regular functions.

In a moment, we'll update this so that the tasks can run concurrently. But first, let's consider the timing of this code. The output above appears over the course of about five seconds—1250ms for delivering the windows, 750ms for the doors, and one second for each call to **`perform()`**. (The delivery times were specified in the enum class back in Listing 20.1).




Now, in Rusty's most recent project, Bot-1 called one warehouse for the windows, then immediately called the other warehouse for the doors. After that, he started laying the bricks, all without waiting for the deliveries.

As we've discovered, if we want to do things concurrently in Kotlin, we can't just throw our code into a single coroutine—we need two or more coroutines. So let's update our code from Listing 20.13 so that Bot-1 can lay the bricks while waiting on the deliveries.

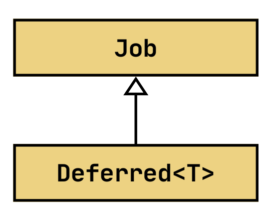
One idea is to wrap each of our **`order()`** calls with a **`launch()`** coroutine builder, and then all of the **`perform()`** calls in another **`launch()`**. That way, the two **`order()`** calls will happen in their own coroutines, concurrently with the brick-laying. When we do this, though, we'll get a compiler error.

```
fun main() {
    runBlocking {
        val windows = launch { order(Product.WINDOWS) }
        val doors = launch { order(Product.DOORS) }
        launch {
            perform("laying bricks")
            perform("installing ${windows.description}")
            perform("installing ${doors.description}")
        }
    }
}
```

*Listing 20.14 - **Error:** Unresolved reference: description.*

The reason for this error is that **`launch()`** does not return the result of **`order()`**. Instead, it returns an object whose type is **`Job`**. This **`Job`** object is helpful, as we'll see later in this chapter, but it doesn't give us any way to get the result of the call to **`order()`**.

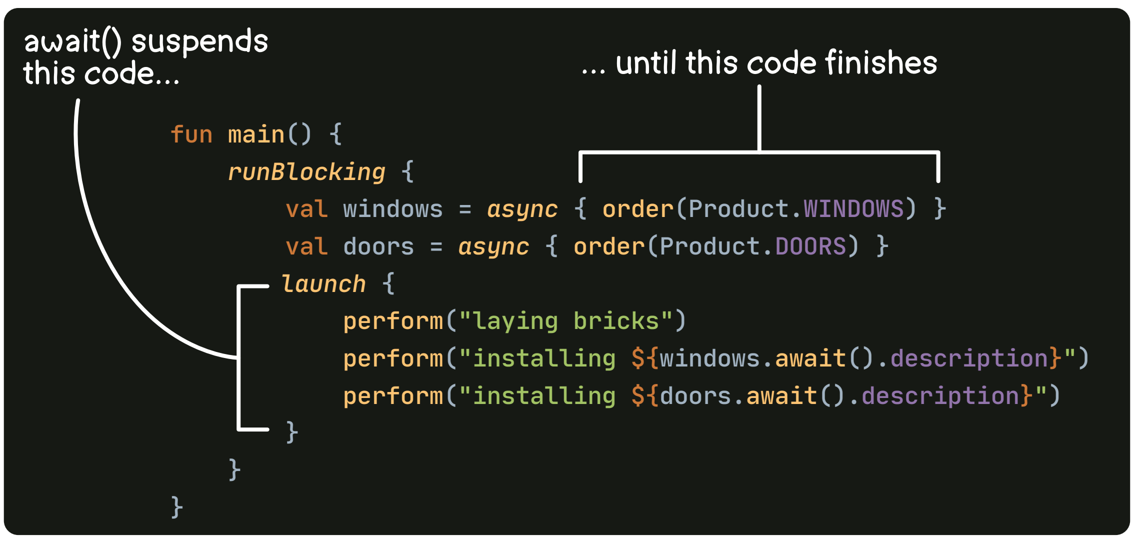
Instead, we'll need to use a *third* kind of coroutine builder, named **`async()`**. This builder works a lot like **`launch()`**, but instead of returning a **`Job`** object, it returns an object that is a subtype of **`Job`**, named **`Deferred`**. This object gives us a function named **`await()`**, which allows us to get the result from **`order()`**. Here's how we can use it.



```kotlin
fun main() {
    runBlocking {
        val windows = async { order(Product.WINDOWS) }
        val doors = async { order(Product.DOORS) }
        launch {
            perform("laying bricks")
            perform("installing ${windows.await().description}")
            perform("installing ${doors.await().description}")
        }
    }
}
```

*Listing 20.15 - Calling **`await()`** to get the resulting products.*

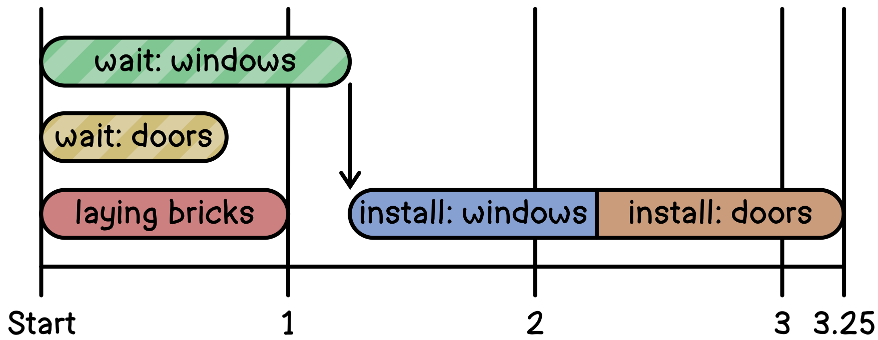
In this code, after laying the bricks, we call **`await()`** on both of the **`Deferred`** objects—the deferred windows and the deferred doors. **`await()`** is a suspending function, and it will suspend the coroutine until its **`async()`** coroutine has completed.



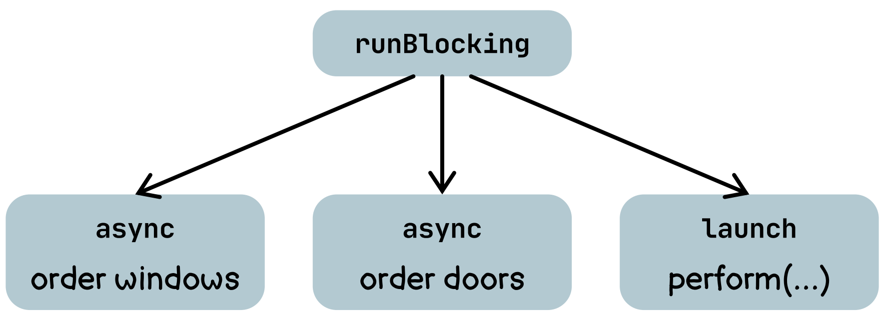

If the windows arrived while the bricks were still being laid, then the windows will be installed as soon as the bricks are finished. If they haven't arrived by the time the bricks are finished, then the coroutine created by **`launch()`** will be suspended until **`order(Product.WINDOWS)`** has completed. Here's the output that we get.

```
ORDER EN ROUTE  >>> The windows are on the way!
ORDER EN ROUTE  >>> The doors are on the way!
STARTING TASK   >>> laying bricks
FINISHED TASK   >>> laying bricks
ORDER DELIVERED >>> Your doors have arrived.
ORDER DELIVERED >>> Your windows have arrived.
STARTING TASK   >>> installing windows
FINISHED TASK   >>> installing windows
STARTING TASK   >>> installing doors
FINISHED TASK   >>> installing doors
```

Just like Rusty, by making these changes, we end up saving quite a bit of time! Instead of taking 5 seconds, this code now takes only 3.25 seconds to complete.




With the code in Listing 20.15, we've got a coroutine structure that looks like this.




It's almost time to get back to Rusty, but before we do, let's review a few concepts from this section.

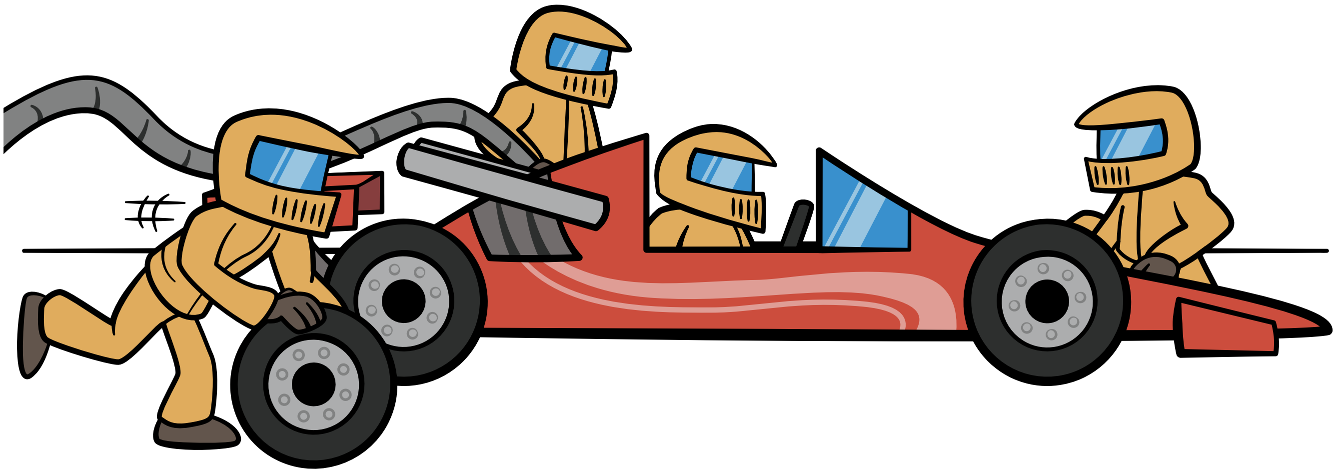
- The `launch()` builder returns a `Job` object, so it's the right choice when we do not need a result from that coroutine.
- The `async()` builder creates a coroutine, and returns a `Deferred` object. We can call the `await()` function on this object to wait for its result.

Rusty and Bot-1 saw some great gains by doing work concurrently, but they're about to find ways to speed up their projects even more! Let's see what they're up to!

# Two Robots, Two Things at a Time...

Later that night, Rusty relaxed at home, enjoying a car-racing event on television. As one race car swooped into a pit stop, he was amazed by the pit crew's efficiency! Within seconds, they jacked up the car, replaced the tires, and filled up the gas tank.

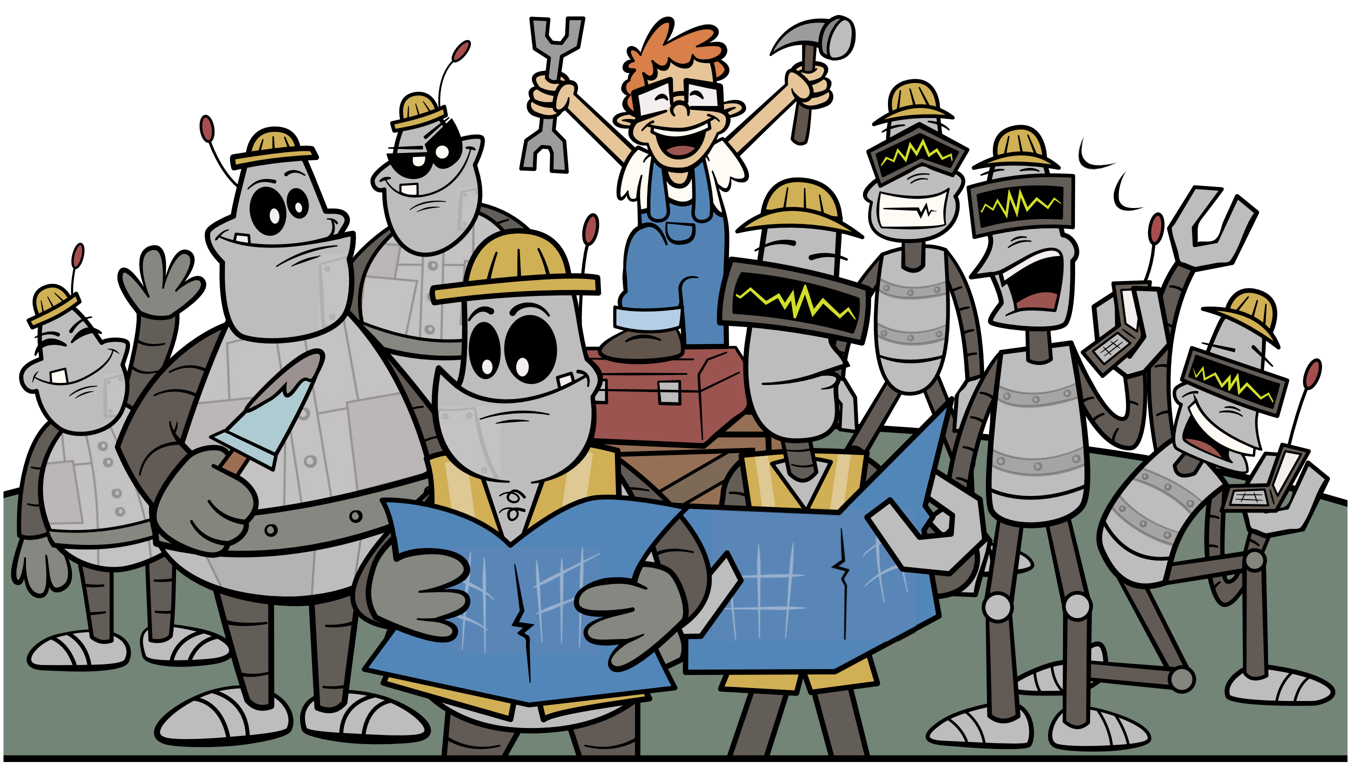
All of this happened so quickly because the pit crew had *multiple* team members, all doing *different* things at the same time. Rusty said to himself, "If I had *multiple* robots in my construction crew, I bet we could speed up our projects even more!"



So the next day, Rusty got to work creating more robots. While building them, he considered the kinds of tasks involved in his projects. Some tasks involve hard work like moving and laying bricks, but other tasks only involve phoning for supplies and watching for the delivery. So, he split up his robots into different teams.

- The first team was tasked with doing the hard work and heavy lifting. He called them the "Default" Team, because they do the main construction work.
- The second team was called the "IO" Team, because they handle input (I) and output (O)—or, "inbound" and "outbound"—communications with facilities that are offsite.

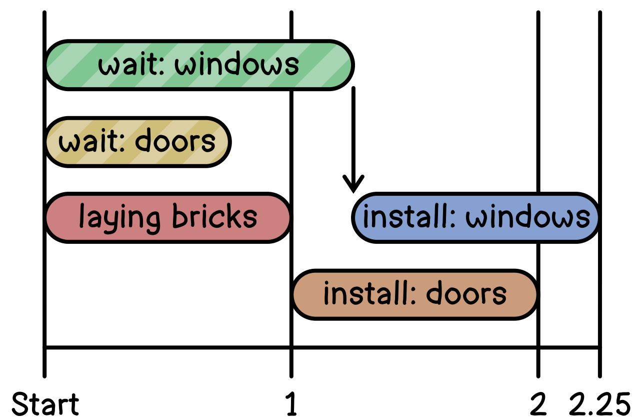
Each team also had a *foreman* who was responsible for assigning tasks to the different robots at different times, depending on the need of the moment.



When the next work order came in, Rusty was excited to try out his new crew of robots!

- The robots on the IO Team called the warehouses to order the windows and doors, and watched for their arrival.
- Meanwhile, the Default Team got started laying the bricks.
- The doors were delivered first, but the Default team wasn't done laying the bricks. Since the bricks have to be done before installing the doors, the doors sat on the side for a little while.
- Once the bricks were done, a robot started installing the doors.
- Soon, the second delivery truck showed up with the windows. A second bot on the Default Team was ready to install the windows as soon as they arrived, so that the windows and doors were being installed at the same time.

This saved even more time than in the previous project!




Rusty was thrilled. Not *everything* could happen at once, of course. The bricks *still* had to be laid before the windows and doors could be installed. However, by installing windows and doors at the same time, his project was completed in record time!

If we want to accomplish the same thing in our Kotlin code, we need to start by learning about threads, concurrency, and parallelism.

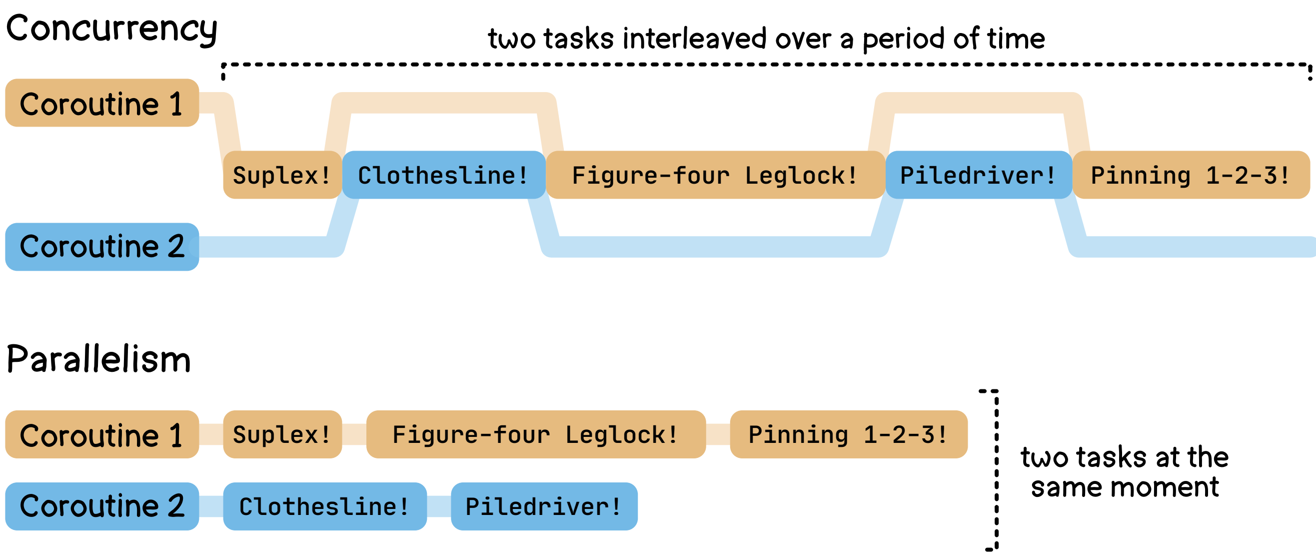
## Multithreaded Concurrency

Anything you run on your computer—whether it's your own Kotlin program, an application that you installed, or a service running the background—runs on a **thread** in the operating system.[1] Since most computers these days have more than one processor core, they can process multiple threads at the same moment.

[1] In most operating systems, each thread is also owned by a **process**, which contains resources and other context. So, a process can have one or more threads. For more information about this topic, consider reading Grokking Concurrency by Kirill Bobrov (2024), published by Manning Publications.

Just like with Rusty's robots, we could use a single thread to do multiple things over a period of time, but if our computer has a multi-core processor we can also use multiple threads to do multiple things at the same moment.[1] This brings up an important distinction.

- When a single execution path of our code bounces back and forth between two or more tasks, those tasks are running **concurrently**.
- When there are multiple execution paths, each running a different task at the same moment, those tasks are running **in parallel**.




So far, our coroutines have run code concurrently, but always on a single thread. Let's get those coroutines running on multiple threads, so that they can run *in parallel!*

When we last left our code in Listing 20.15, it looked like this.

```
fun main() {
    runBlocking {
        val windows = async { order(Product.WINDOWS) }
        val doors = async { order(Product.DOORS) }
        launch {
            perform("laying bricks")
            perform("installing ${windows.await().description}")
            perform("installing ${doors.await().description}")
        }
    }
}
```

*Listing 20.16 - Code from Listing 20.15, which runs concurrently, but not in parallel.*

[1] Even if your computer has a single core, you typically can still use multiple threads. The work of these threads will get sliced up so that each thread gets a little time on the processor. In fact, it works a lot like the coroutines we've created so far, except that instead of *choosing* to tag out (cooperative multitasking), the thread is *kicked* out at some point—it's like the referee blows a whistle and kicks the wrestler out of the ring, and calls him back in later (preemptive multitasking).

Just like each of Rusty's teams had a foreman who assigned tasks to the robots on that team, in Kotlin, we've got different **dispatchers** that can assign coroutines to run on the threads they manage.

If we want a particular dispatcher to manage a coroutine, we simply pass the dispatcher as an argument to the coroutine builder.

For example, we can assign the product-ordering tasks to the IO Team, by passing `Dispatchers.IO` to the coroutine builder. The rest of the tasks can go to the Default Team, by passing `Dispatchers.Default`.

```
fun main() {
    runBlocking {
        val windows = async(Dispatchers.IO) { order(Product.WINDOWS) }
        val doors = async(Dispatchers.IO) { order(Product.DOORS) }
        launch(Dispatchers.Default) {
            perform("laying bricks")
            perform("installing ${windows.await().description}")
            perform("installing ${doors.await().description}")
        }
    }
}
```

*Listing 20.17 - Running tasks on three different threads.*

## Technically Speaking: Default vs. IO

What's the real difference between `Dispatchers.Default` and `Dispatchers.IO`? Technically, it's entirely possible to give CPU-heavy work to the `IO` dispatcher and IO-heavy work to the `Default` dispatcher.

- The `Default` dispatcher has a thread pool with one thread for each processor core in your computer, so if your computer has 8 cores, its thread pool has 8 threads.
- The `IO` dispatcher will scale up its number of threads to 64 threads, by default. (If your computer has more than 64 cores, then it'll scale up to the number of cores).

`Default` is a great choice for most cases, especially when the coroutines need CPU time. `IO` is especially helpful when you want to get a blocking I/O library to work concurrently.

Previously, everything was running on a single thread—in other words, one robot was doing every task. But now, by assigning the coroutines to `Dispatchers.IO` and `Dispatchers.Default`, the work is happening on *three* different threads.

- Two threads managed by the **IO** dispatcher order the products and keep a lookout for their delivery.
- One thread managed by the **Default** dispatcher is laying the bricks, then installing the windows, and finally installing the doors.

Even though we've assigned the work to different teams, this work is still taking three seconds to complete. In order to speed this up even more, we need to install the windows and doors in parallel.

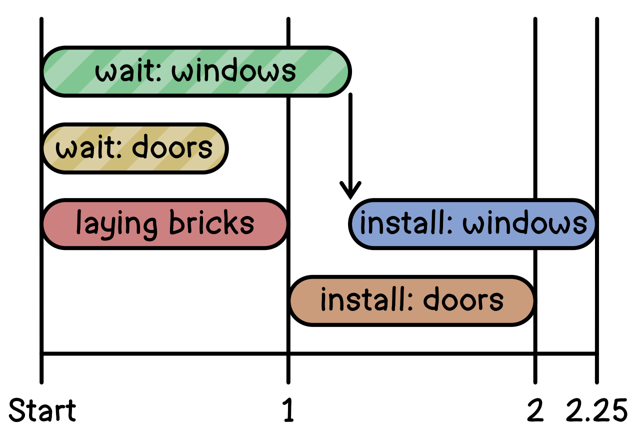
As usual, we need to put a coroutine builder around the code that we want to run concurrently or in parallel with our other code. Let's wrap the last two **perform()** calls with another **launch()**.

Note that, because the bricks must be laid before the windows and doors can be installed, we're not launching these coroutines until *after* that work has finished.

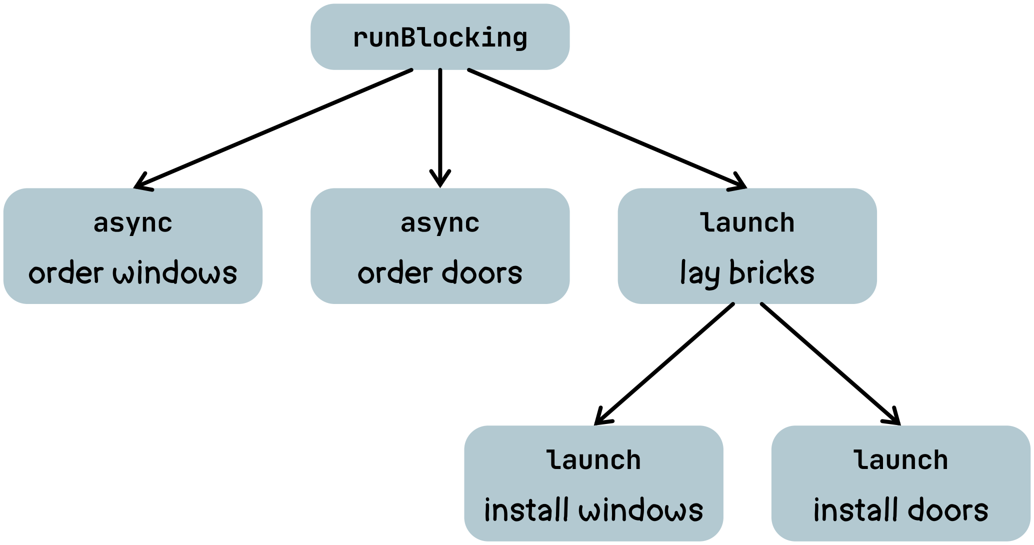
```
fun main() {
    runBlocking {
        val windows = async(Dispatchers.IO) { order(Product.WINDOWS) }
        val doors = async(Dispatchers.IO) { order(Product.DOORS) }
        launch(Dispatchers.Default) {
            perform("laying bricks")
            launch { perform("installing ${windows.await().description}") }
            launch { perform("installing ${doors.await().description}") }
        }
    }
}
```

*Listing 20.18 - Installing the windows and doors in their own coroutines.*

With this change, the windows and doors are installed at the same time, completing all of the work in only 2.25 seconds!




This code creates six different coroutines—one with **runBlocking()**, two with **async()**, and three with **launch()**. The result is a hierarchy of coroutines that looks like this.




This works like we want, but we can also do this more efficiently by using a function named `withContext()`.

## `withContext()`: Handing Work to Another Dispatcher

So far, we've separated the code that *orders* a product from the code that *installs* the product.

```
fun main() {
    runBlocking {
        val windows = async(Dispatchers.IO) { order(Product.WINDOWS) }
        val doors = async(Dispatchers.IO) { order(Product.DOORS) }
        launch(Dispatchers.Default) {
            perform("laying bricks")
            launch { perform("installing ${windows.await().description}") }
            launch { perform("installing ${doors.await().description}") }
        }
    }
}
```

ordering windows and doors up here

laying bricks

installing windows and doors down here

However, *ordering* a product and *installing* a product are closely-related concepts, so it could be helpful to keep those tasks near to each other in the code. For example, to keep the window-ordering code and the window-installing code near to each other—yet still ensure that the correct team is responsible for each step—we can use a function named `withContext()`.

The `withContext()` function allows us to *switch the dispatcher* of a coroutine.

In other words, it's like a robot on the IO Team placing the order and waiting for its arrival; then, once it arrives, it hands the windows over to a robot on the Default Team to do the actual installation work. Here's how the code would look.

```kotlin
fun main() {
    runBlocking {
        launch(Dispatchers.IO) {
            val windows = order(Product.WINDOWS)
            withContext(Dispatchers.Default) {
                perform("install ${windows.description}")
            }
        }
        launch(Dispatchers.IO) {
            val doors = order(Product.DOORS)
            withContext(Dispatchers.Default) {
                perform("install ${doors.description}")
            }
        }
        launch(Dispatchers.Default) {
            perform("laying bricks")
        }
    }
}
```

*Listing 20.19 - Using* **`withContext()`** *to switch dispatchers.*

In this code, we call **`launch()`** to create three coroutines—once for dealing with the windows, once for dealing with the doors, and once for laying the bricks.

Within the first two, the product is ordered on a thread managed by **`Dispatchers.IO`**. But, once the product has arrived, we use **`withContext()`** to change the dispatcher, so that **`perform()`** happens on a thread that's managed by **`Dispatchers.Default`**.

```
                                launch(Dispatchers.IO) {
runs on an IO thread     →          val windows = order(Product.WINDOWS)
                                    withContext(Dispatchers.Default) {
runs on a Default thread →              perform("install ${windows.description}")
                                    }
                                }
```

By making this change, the related work (e.g., ordering the windows and installing the windows) stays closer together in the code.

We've introduced a problem, though! The windows and doors are supposed to be installed only *after* the bricks have been laid. When we look at the output from Listing 20.19, we'll notice that we start installing doors *before* the bricks job has finished!

How can we wait for the bricks job to finish before we start installing the doors and windows?

```
STARTING TASK   >>> laying bricks
ORDER EN ROUTE  >>> The windows are on the way!
ORDER EN ROUTE  >>> The doors are on the way!
ORDER DELIVERED >>> Your doors have arrived.
STARTING TASK   >>> install doors
FINISHED TASK   >>> laying bricks
ORDER DELIVERED >>> Your windows have arrived.
STARTING TASK   >>> install windows
FINISHED TASK   >>> install doors
FINISHED TASK   >>> install windows
```

As you might remember, when we call the **`async()`** builder, it returns a **`Deferred`** object, and we can call **`await()`** on this object to suspend the coroutine until the result is ready. Similarly, the **`launch()`** builder returns a **`Job`** object, which includes a function named **`join()`**. Like **`await()`**, the **`join()`** function suspends the coroutine until the code in the **`launch()`** block has completed. Let's update our code once more. This time, we'll make sure the bricks job has completed before installing the windows and doors.

```kotlin
fun main() {
    runBlocking {
        val bricksJob = launch(Dispatchers.Default) {
            perform("laying bricks")
        }
        launch(Dispatchers.IO) {
            val windows = order(Product.WINDOWS)
            bricksJob.join()
            withContext(Dispatchers.Default) {
                perform("install ${windows.description}")
            }
        }
        launch(Dispatchers.IO) {
            val doors = order(Product.DOORS)
            bricksJob.join()
            withContext(Dispatchers.Default) {
                perform("install ${doors.description}")
            }
        }
    }
}
```

*Listing 20.20 - Calling `join()` on a `Job` object to wait for it to complete.*

Here, we rearranged the **`launch()`** calls so that the bricks job comes first. We assigned the result of that **`launch()`** call to a variable named **`bricksJob`**. Then, inside the remaining two **`launch()`** blocks, we call **`bricksJob.join()`** to suspend until the bricks job is complete. When we run this code, we can see that the doors and windows are not installed until the bricks have been laid.

```
STARTING TASK   >>> laying bricks
ORDER EN ROUTE  >>> The windows are on the way!
ORDER EN ROUTE  >>> The doors are on the way!
ORDER DELIVERED >>> Your doors have arrived.
FINISHED TASK   >>> laying bricks
STARTING TASK   >>> install doors
ORDER DELIVERED >>> Your windows have arrived.
STARTING TASK   >>> install windows
FINISHED TASK   >>> install doors
FINISHED TASK   >>> install windows
```

Rusty and his crew nailed their most recent project, but in the construction world, you never know what wrenches will get thrown into the works! Let's see what challenges they're about to face next!

### By the Way: Main Dispatcher

There are other kinds of dispatchers in addition to **`Default`** and **`IO`**. Another important one to know about is the **`Main`** dispatcher, which is essential when your code needs to update things on the screen like progress bars, icons, and lists. In many UI frameworks, there's only a single thread that is responsible for drawing changes to the screen, and the **`Main`** dispatcher represents that thread. In an Android application, for example, the **`Main`** dispatcher sends the work to the main thread—that is, the same one that the **`runOnUiThread()`** function uses.

We aren't using any UI frameworks in this chapter, though, so we'll stick to the **`Default`** and **`IO`** dispatchers.

# Cancellations

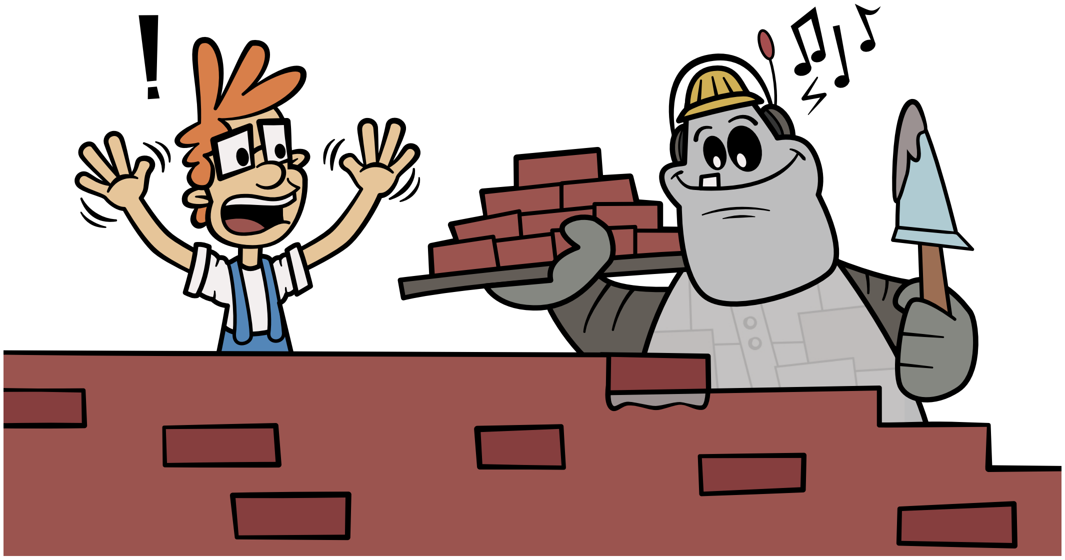
## Canceling the Entire Job

One day, Rusty and his construction crew were busy working on a project when he got a call from the client.

"Hey, Rusty, here's the thing…" began the client, "We're moving our entire operation to another part of town. So you know that building that you're working on? We don't need it any more. Just cancel the whole project."

Well, the team was already in the middle of the job, but if the client didn't need the building any more, it wouldn't make sense to keep working on it. Two robots were waiting for the delivery of the windows and doors, and one was laying the bricks. Rusty ran up and gave the news to each robot. The ones who were waiting for the deliveries got the message right away, so they packed up their things and got ready to go home.

However, Bot-3, who was hard at work with his headphones on, didn't notice Rusty at first. After the final brick was laid, at last he looked up and saw Rusty signaling that everyone was about to head home, so he finally gathered his things and wrapped up.



## Canceling Top-Level Coroutines

Just like at the construction site, sometimes a coroutine job needs to get canceled. We can call a function named **`cancel()`** inside the lambdas that we pass to the coroutines builders. Let's update our code to do so.

```
fun main() {
    runBlocking {
        val bricksJob = launch(Dispatchers.Default) {
            perform("laying bricks")
        }
        launch(Dispatchers.IO) {
            val windows = order(Product.WINDOWS)
            bricksJob.join()
            withContext(Dispatchers.Default) {
                perform("install ${windows.description}")
            }
        }
        launch(Dispatchers.IO) {
            val doors = order(Product.DOORS)
            bricksJob.join()
            withContext(Dispatchers.Default) {
                perform("install ${doors.description}")
            }
        }
        cancel()
    }
}
```

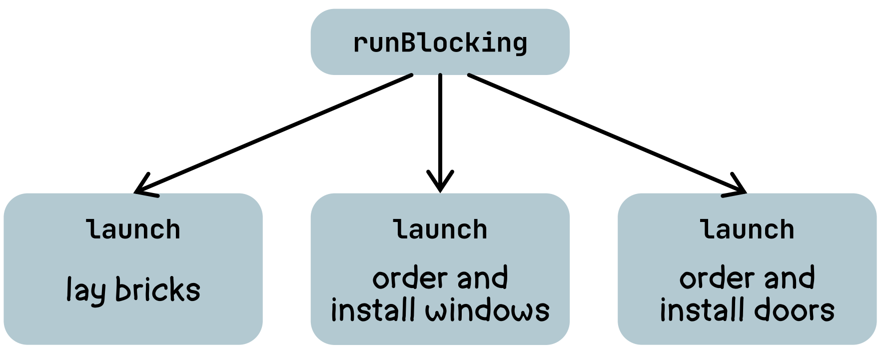
*Listing 20.21 - Canceling a coroutine.*

Running this, we'll see output that looks something like this.

```
STARTING TASK   >>> laying bricks
ORDER EN ROUTE  >>> The windows are on the way!
ORDER EN ROUTE  >>> The doors are on the way!
FINISHED TASK   >>> laying bricks
Exception in thread "main" kotlinx.coroutines.JobCancellationException:
BlockingCoroutine was cancelled; job=BlockingCoroutine{Cancelled}@7006c658
```

By calling `cancel()`, we got a `JobCancellationException`. And just like at Rusty's work site, the bricks task was *not* interrupted. In a moment, we'll learn why this happened. For now, let's take a closer look at how cancellation works.

As we've seen throughout this chapter, when one coroutine launches another (which might launch another!) we end up with a hierarchy of coroutines. In Listing 20.21, the coroutine created by `runBlocking()` ends up creating three other coroutines, resulting in a structure that looks like this.



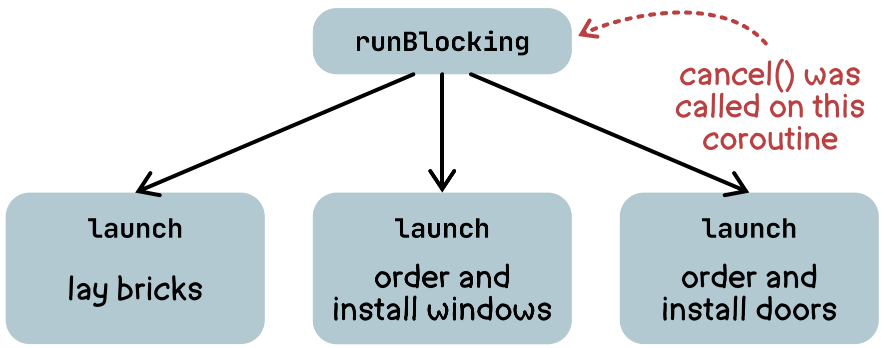

Coroutines that are all part of the same hierarchy exist within the same **coroutine scope**. In fact, `CoroutineScope` is an actual interface, and the `launch()` and `async()` coroutine builders are extension functions on that interface, which allows them to tie their new coroutines to that `CoroutineScope`.

By structuring coroutines into a scope, Kotlin can keep track of that scope's coroutines and the parent-child relationships between them. That way, if work is canceled or something goes wrong, Kotlin will ensure that each coroutine is accounted for, without requiring the developer to handle these situations manually. This feature is called **structured concurrency**. Let's see how structured concurrency applies when a job is canceled.

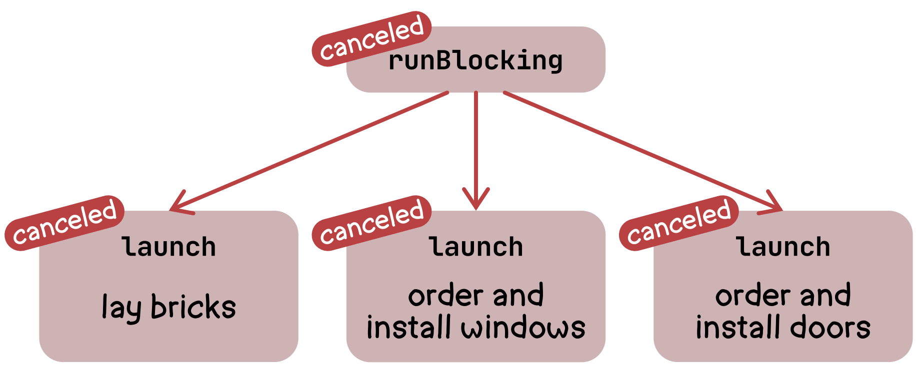
## By the Way: Coroutine Scope

In Chapter 11, we learned all about scopes and scope functions, but don't confuse those with the notion of a *coroutine* scope. Chapter 11 dealt with the scope of *code*, determining which lines of code were grouped together, which functions and variables were visible to that group, and so on. Here we're talking about the scope of *coroutines*, determining which coroutines are grouped together and how they relate to one another.

In Listing 20.21, we called **`cancel()`** inside the **`runBlocking()`** lambda—that is, the coroutine at the *top* of the hierarchy.




Thanks to structured concurrency, when the root coroutine is canceled, we don't need to manually cancel each of its children. Instead, each child coroutine is *automatically* sent a signal to cancel. And if that child happens to have child coroutines of its own, it sends along the cancellation signal to them, as well.




However, just like Bot-3 was focused with his headphones on, not paying attention to Rusty, a coroutine won't notice the cancellation signal *unless it remembers to look for it.*

It's been a while, but let's look at the code for the **`perform()`** function from Listing 20.2 again.

```kotlin
fun perform(taskName: String) {
    println("STARTING TASK   >>> $taskName")
    Thread.sleep(1_000)
    println("FINISHED TASK   >>> $taskName")
}
```

*Listing 20.22 - The original* **`perform()`** *function, from Listing 20.2.*

In order to simulate the time it takes to perform a task, this function is using **`Thread.sleep()`**. Since the thread running this code is busy the whole time, it never looks up to see if the job is canceled.

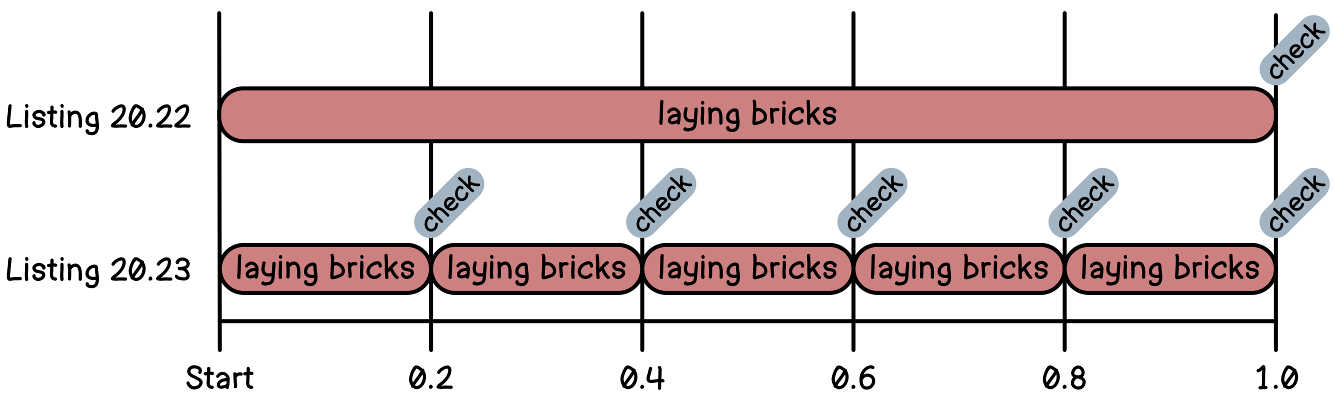
Instead of doing work for 1000 milliseconds straight, let's divide up the work into five units, so that the robot gets a break every 200 milliseconds. We'll use a function named **`repeat()`** to loop five times, and then sleep for only one-fifth of the time on each iteration.

We'll call **`yield()`** to take a break. This will give our robot a chance to notice if the job has been canceled. Remember, we can't call a suspending function from a regular function. Since **`yield()`** is a suspending function, we have to make **`perform()`** a suspending function, too.

```
suspend fun perform(taskName: String) {
    println("STARTING TASK   >>> $taskName")
    repeat(5) {
        Thread.sleep(200)
        yield()
    }
    println("FINISHED TASK   >>> $taskName")
}
```

*Listing 20.23 - Splitting up long-running work into smaller units of work, using* **`yield()`** *to check for cancellation.*

By calling the **`yield()`** function every once in a while, this gives the coroutine a chance to look up to see if the work has been canceled.




Running the code again now produces output that looks like this.

```
STARTING TASK   >>> laying bricks
ORDER EN ROUTE  >>> The windows are on the way!
ORDER EN ROUTE  >>> The doors are on the way!
Exception in thread "main" kotlinx.coroutines.JobCancellationException:
BlockingCoroutine was cancelled; job=BlockingCoroutine{Cancelled}@7006c658
```

This time, the thread that was laying the bricks had a chance to notice that the job was canceled, so it quit the work *without* finishing it.

This demonstrates that cancellation in coroutines is **cooperative**. A coroutine that's hard at work (laying bricks or running computations) will not notice a cancellation unless it takes an occasional break from its work. If its code doesn't *cooperate* by choosing to check for cancellation, it won't notice the signal.

We can check for cancellation by calling **`yield()`**, as we're doing in Listing 20.23 above. Alternatively, we can check the **`isActive`** property of the **`CoroutineScope`**, or by calling its **`ensureActive()`** function.

The good news is that many suspending functions in real projects—such as those in the coroutines library, the Ktor client library, and so on—are written in a way that they'll notice the cancellation.

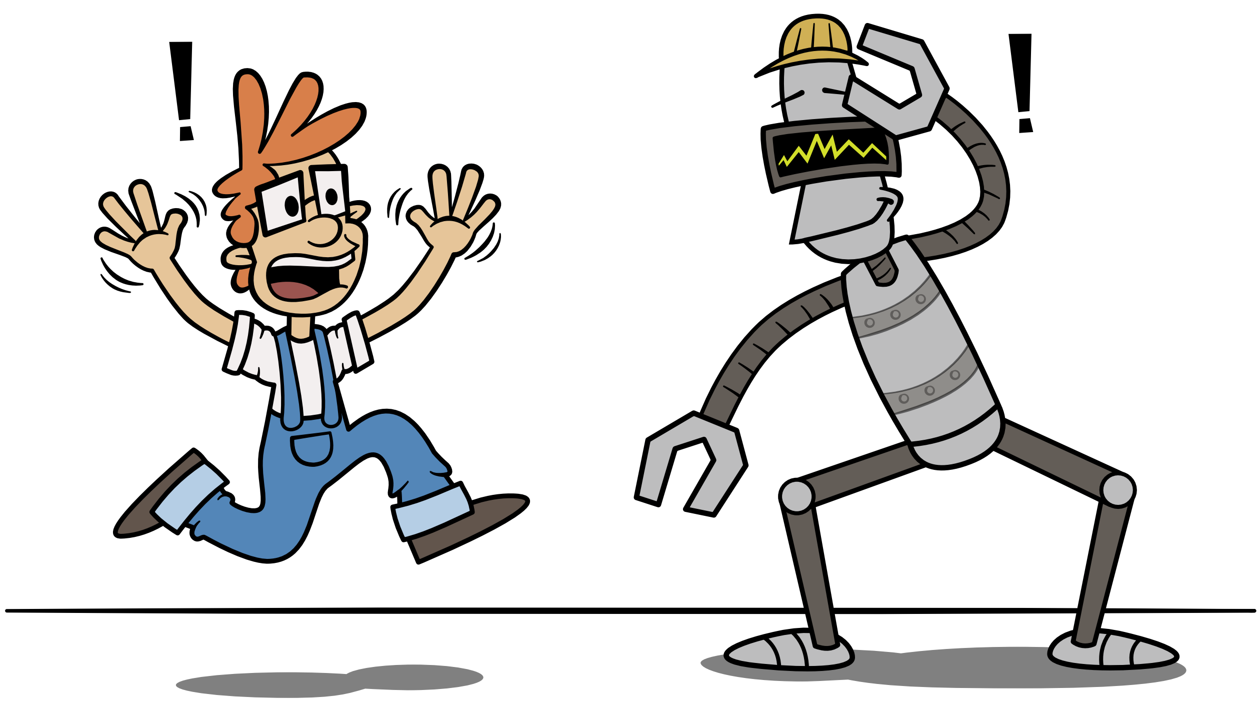
But if you've got a coroutine that's doing some heavy lifting, be sure it has a chance to suspend once in a while, so that it can quickly respond to cancellations without doing unnecessary work.

Not all cancellations have to affect the entire job, though, as Rusty and his crew are about to find out!

## Canceling Part of a Job

One day as the crew was hard at work constructing another building, the client called, saying "I know you've already started installing the doors, but we decided that we prefer an open-air feeling, so don't bother installing the doors. I still want the building—just without the doors."

This time, instead of telling *all* of the robots to stop working, Rusty went directly to the robot who was waiting on the door delivery, and gave him the cancellation signal. The windows were still installed, and the building was completed successfully without the doors.




### Canceling a Child Coroutine

As we saw earlier, because of structured concurrency, when we cancel a coroutine, that coroutine is canceled along with all of its children. However, the cancellation does *not* affect parent or sibling coroutines.

To demonstrate this, let's cancel the *door* job, like Rusty's client did.

```
fun main() {
    runBlocking {
        val bricksJob = launch(Dispatchers.Default) {
            perform("laying bricks")
        }
        launch(Dispatchers.IO) {
            val windows = order(Product.WINDOWS)
            bricksJob.join()
            withContext(Dispatchers.Default) {
                perform("install ${windows.description}")
            }
        }
        launch(Dispatchers.IO) {
            val doors = order(Product.DOORS)
            bricksJob.join()
            cancel()
            withContext(Dispatchers.Default) {
                perform("install ${doors.description}")
            }
        }
    }
}
```

*Listing 20.24 - Canceling the installation of the doors does not cancel the installation of the windows.*

Back in Listing 20.21, the call to **`cancel()`** happened immediately inside the root coroutine—that is, the lambda passed to **`runBlocking()`**. Here, however, the call to **`cancel()`** happens inside one of the child coroutines—the one that installs the doors.

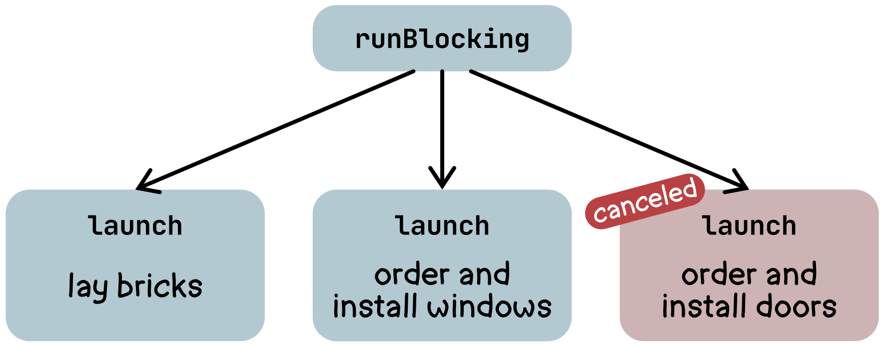
When we run this, we get output that looks like this.

```
STARTING TASK   >>> laying bricks
ORDER EN ROUTE  >>> The windows are on the way!
ORDER EN ROUTE  >>> The doors are on the way!
ORDER DELIVERED >>> Your doors have arrived.
FINISHED TASK   >>> laying bricks
ORDER DELIVERED >>> Your windows have arrived.
STARTING TASK   >>> install windows
FINISHED TASK   >>> install windows
```

This works exactly as we hoped it would!

Notice that the doors arrived, but they were never installed. Everything else continued according to plan—the bricks were laid, and the windows were installed.

So, when we cancel a coroutine, that coroutine itself is canceled, and if it has any children, they are also canceled. But parent and sibling coroutines are unaffected.




Cancellation isn't the only surprise that can affect a job, though, as Rusty and his crew are about to find out!

### By the Way: Canceling from Outside

In the code above, the coroutine canceled itself by calling **`cancel()`** inside its suspending lambda.

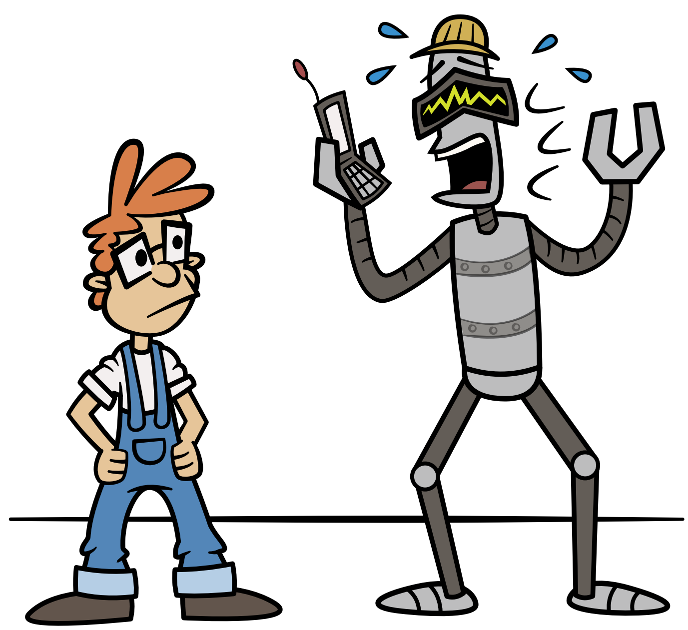
However, it's also possible to cancel a coroutine from *outside* of its body. As we've seen, when we create a coroutine, we get a **`Job`** or **`Deferred`** object back. We can call **`cancel()`** on that object, as well.

```
val job = launch { perform("laying bricks") }
job.cancel()
```

## When We Can't Recover From a Problem

One day, the construction crew was back at it, working on one more construction project. While the bricks were being laid, one of the robots on the IO team called to request the delivery of the doors. However, the warehouse gave him some surprising news.

"Sorry, but we can't deliver those doors to you. Your client has exceeded his budget limits, and he can't afford any more doors," said the voice on the other end of the phone.



Without the doors, and indeed, without any more money, the project simply couldn't continue. The robot canceled his work, then ran up to Rusty to inform him of the situation. "Well, it looks like we're going to have to abandon this project," said Rusty, who then walked over to the rest of his crew and signaled for them to stop their work.

## Exceptions in Coroutines

Sometimes there are unrecoverable problems. In Chapter 17, we learned all about exceptions, and how an exception that isn't caught will eventually work its way to the beginning of the call stack, causing the entire app to crash. There's a similar situation with coroutines, but it also involves canceling work that's in progress. To demonstrate this, let's throw an exception inside the coroutine that is ordering doors.

```
fun main() {
    runBlocking {
        val bricksJob = launch(Dispatchers.Default) {
            perform("laying bricks")
        }
        launch(Dispatchers.IO) {
            val windows = order(Product.WINDOWS)
            bricksJob.join()
            withContext(Dispatchers.Default) {
                perform("install ${windows.description}")
            }
        }
        launch(Dispatchers.IO) {
            val doors = order(Product.DOORS)
            throw Exception("Out of money!")
            bricksJob.join()
            withContext(Dispatchers.Default) {
                perform("install ${doors.description}")
            }
        }
    }
}
```

*Listing 20.25 - An uncaught exception cancels all of the related coroutines.*

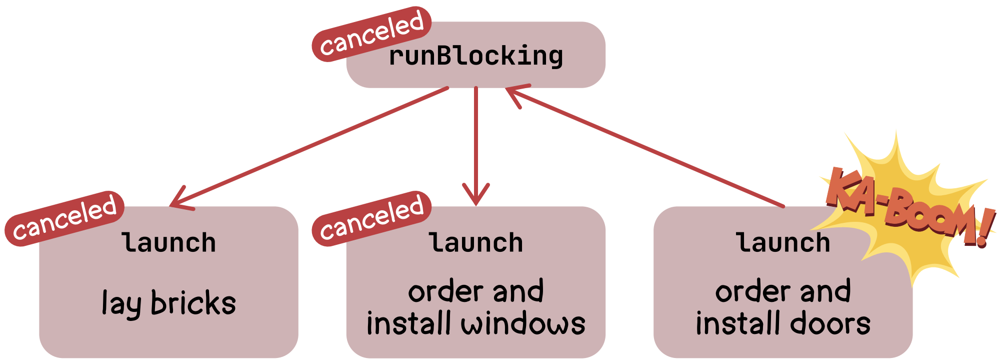
When running this, we'll see output that looks something like this.

```
STARTING TASK   >>> laying bricks
ORDER EN ROUTE  >>> The doors are on the way!
ORDER EN ROUTE  >>> The windows are on the way!
ORDER DELIVERED >>> Your doors have arrived.
Exception in thread "main" java.lang.Exception: Out of money!
```

Although the work was started for each of the three jobs, *none* of them finished, because of the exception that was thrown from inside the door job.

By default, an uncaught exception inside a coroutine will affect all of the coroutines within its scope.

- The coroutine with the uncaught exception will cancel all of its children.
- Then, it hands the exception up to its parent, who in turn cancels all of its children, who will in turn cancel any children that *it* has, and so on.
- This process continues until the exception reaches the top of the coroutine hierarchy.




This behavior—canceling children and propagating exceptions upward throughout the coroutine scope—is another feature of structured concurrency. As with cancellation, it removes a lot of manual work that we would otherwise have to do ourselves to ensure that all of the coroutines are properly shut down.

## By the Way: Supervisors

This default behavior is exactly what we want most of the time, but there are occasions when you might want to limit the blast radius of an exception.

If you want to keep the sibling and parent coroutines running when an exception happens, you can use `SupervisorJob` or `supervisorScope()`. More information about supervisors can be found in the official Kotlin documentation.

# Summary

As the sun set over the skyline, Rusty stood admiring the work that he and his construction crew had accomplished. His most recent projects turned out great and were completed so much faster than the earlier projects when Bot-1 was wasting time sitting on the curb.

Taking inspiration from tag-team wrestlers and racing pit crews, Rusty and his bots worked their tasks concurrently and in parallel, which enabled them to finish their projects in record time!

As the robots powered down for the night, Rusty kicked back on his sofa, imagining what it would be like to one day build a skyscraper.

Most software projects these days needs some amount of concurrency, and in this chapter, we learned:

- How coroutines create concurrency, with an execution path that bounces back and forth between functions—like tag-team wrestlers.
- How to use coroutines to do more than one thing at a time—like laying bricks while awaiting deliveries.
- How to use coroutines to do more than one thing at the same moment, in parallel.
- How to use `withContext()` to hand work off to another dispatcher.
- How structured concurrency affects cancellation of coroutines in a hierarchy.
- How structured concurrency affects exceptions that are thrown within a coroutine.

Congratulations on working your way through this chapter! Coroutines can be a challenging topic for many developers, but with these essentials under your belt, you'll be prepared to use them with confidence!

Appendix A

# How to Run the Code Listings

There are several ways to write and run Kotlin code. The most common way is to write Kotlin (.kt) files or Kotlin Script (.kts) files in an **integrated development environment**, or **IDE**—which is an app where you can write, build, and run your code.

Kotlin is primarily developed by JetBrains, the creators of a popular IDE named *IntelliJ IDEA*. So it makes sense to use IntelliJ when working with Kotlin. If you're an Android developer, you might already be familiar with *Android Studio*, which is built on top of IntelliJ. Both are excellent options for Kotlin development, but for this book, you'll probably prefer IntelliJ, so that you can focus on Kotlin apart from Android.

If you don't already have it, you can download IntelliJ IDEA from the JetBrains website: https://www.jetbrains.com/idea/

Once you've got IntelliJ IDEA downloaded and installed, you'll be ready to start working with Kotlin code. You can download the source code for this book, or you can create your own project, where you can enter the code yourself.

## Loading the Sample Code Project

The code listings in this book are assembled into a Kotlin project, which you can find here: https://github.com/typealias-studios/kotlin-illustrated-guide.

If you're familiar with Git, just clone that repository. Otherwise, click the **Code** button on that page, select **Download ZIP**, and extract the contents to a folder named `kotlin-illustrated-guide` somewhere on your hard drive.

Once you've got a copy of that project, open IntelliJ IDEA and click **Open** from the welcome screen. If you've already got a project open, just go to **File** > **Open**.

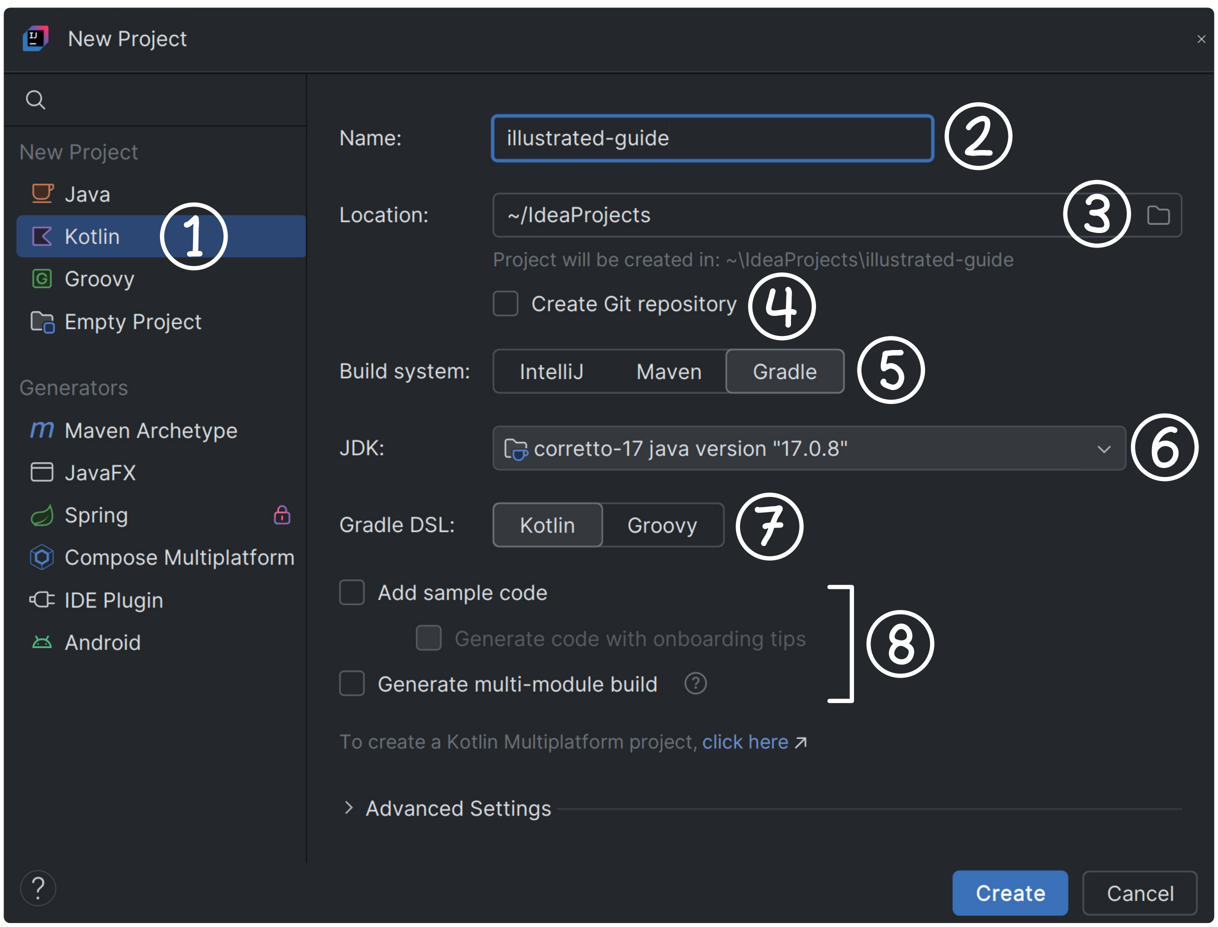
Find the `kotlin-illustrated-guide` folder that you cloned or downloaded, and hit **OK**. If you don't already have a Java Development Kit (JDK) that can build this project, you'll be prompted to download one. You'll see a progress bar near the bottom right corner of the screen. Wait for that to complete. Once it does, you'll be ready to start exploring the code.

Be sure to read the `README.md` file, which explains how the project is organized!

# Creating a Kotlin Project

It can be helpful to consult the code samples project, but most of us learn best by actually writing the code ourselves. So instead of using the code samples project, you might want to create your own Kotlin project to play with. Here's how you can do that.

From the welcome screen, click **New Project**. Or, if you've already got a project open, go to **New** > **Project**. This opens the *New Project* window.




1. From the options along the left-hand side, choose **Kotlin**.

2. **Name** - This is the name of your project. It can't include spaces or punctuation, so if you want multiple words in the name, use a hyphen between words or use capital letters to separate the words. For example, `illustrated-guide` or `IllustratedGuide`.

3. **Location** - This is where the project will be saved on your hard drive.

4. **Create Git repository** - If you're already familiar with how to use Git for version control, you can check this box. If you haven't used version control before, you can leave this unchecked.

5. **Build system** - You'll usually want to choose Gradle, which is common in the Kotlin world, especially when working with projects that target multiple platforms. If you're already familiar with Maven, though, you can choose that.

6. **JDK** - Kotlin code is usually configured to run on the Java Virtual Machine (JVM). To create a project that can run on the JVM, you'll need the tools to create it—a Java Development Kit (JDK). If you've already got a JDK installed on your system, you can choose it from this drop-down field. Otherwise, IntelliJ will download one for you. At the time of writing, I recommend either JDK 17 or 21, both of which have *long-term support* and work well with Gradle.

7. **Gradle DSL** - Assuming you chose Gradle as the build system, you'll see an option for either Kotlin or Groovy. This tells IntelliJ what language you'd like to use for your build script—instructions that tell Kotlin how your project is structured, what libraries you depend on, and so forth. Since your main source code will be written in Kotlin, it makes sense to use Kotlin for the build script, too. Choose Kotlin for this option unless you've got a specific reason to use Groovy.

8. For the rest of the check boxes, I'd recommend leaving them unchecked.

From here, you can hit the **Create** button. If you need to download a JDK, you'll get prompted to choose one. If you're familiar with the JDK options out there, you can choose the one that you prefer. Otherwise, you can just go with the default.

After that, you'll notice the progress bar at the bottom of the screen. Once that finishes, you're ready to start writing Kotlin code!

## Adding Kotlin Script (.kts) Files

In the first two chapters, we'll explore foundational concepts like variables, types, and functions. For these chapters, I recommend starting with Kotlin script (.kts) files.

Here's how you can create a script file in your new project.

1. On the left-hand side of the IDE, you should see a section with the heading, **Project**. This includes all of the files, folders, and libraries in your project. At the top of that section should be the name of your project, such as `illustrated-guide`. Right-click that, and choose **New**, then **Directory**. Name the new directory `scripts`, and then press Enter. This creates a new folder in the root of your project.

2. Now right-click the `scripts` folder that you just created, and choose **New** and **Kotlin Script**. Name it `FirstScript` and hit Enter. Congratulations—you've added your first Kotlin script file, and you're ready to start writing some code!

To test things out, you can enter the following code.

```
val r = 5.2
println(r)
```

Finally, at the top of the IDE, you'll see a green "Play" button. Click on that to run your code. At the bottom of the screen, you'll see something like this.

```
5.2

Process finished with exit code 0
```

This shows the value of the variable `r`, and tells us that the script finished running with exit code `0`, which means it completed successfully. Although not shown in the output above, note that it also includes a line at the top with command-line details.

## Adding Kotlin (.kt) Files

By the end of Chapter 2, you'll learn about the `main()` function, at which point you'll be ready to move on to writing more advanced code using regular Kotlin (.kt) files. Here's how you can create those.

In the Project area on the left side of the IDE, expand the `src` folder. Inside that folder should be *another* folder named `main`. Inside *that* folder should be *another* one, named `kotlin`. Right-click that `kotlin` folder, and choose New and Kotlin Class/File. Name it `Main`, and choose **File** from the list of Kotlin file types. Then hit Enter.

Now you can add code to the new Main.kt file. Unlike with Kotlin Script files, if you want to run the code in a regular Kotlin file, you'll need a `main()` function, as explained in Chapter 2. For example, you can enter the following code in Main.kt, which will get it to do the same thing as in `FirstScript.kt`.

```
fun main() {
    val r = 5.2
    println(r)
}
```

To run this `main()` function, click on the green play icon to its left. Then choose "Run 'MainKt'", and watch your code run!

```
5.2

Process finished with exit code 0
```

# Other Ways to Write and Run Kotlin Code

## Explore the Online Playground

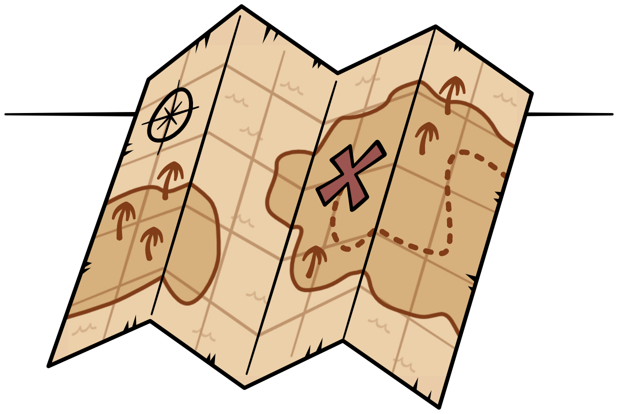
If you're not ready to install any software yet, you can experiment with Kotlin code using the online playground at https://play.kotlinlang.org. The playground supports basic code completion and is perfect for quick experiments, but it's limited compared to a full IDE. It's a good place to start, but you'll eventually want a more powerful editor.

## Advanced Options

There are more ways to run Kotlin code besides the ones mentioned above. If you're a more advanced developer, you can write your code in any text editor and build it using Kotlin's command-line tooling. And if you've got a license for *IntelliJ IDEA Ultimate*, you can use its notebook feature. However, the free *Community Edition* of IntelliJ IDEA is more than enough to run the code in this book.

## Appendix B

# Adding Dependencies



In most of this book, we focus on features of the Kotlin language and its standard library. However, the Kotlin world extends far beyond the standard library! And if your Kotlin code is targeting the JVM, you can also tap into the wide ecosystem of Java libraries. So if you want a library that helps you connect to a database or turn your data classes into JSON strings, you've got lots of options.

When you add a library to your project, it becomes a **dependency**. The first step to including a dependency is to identify the library's **coordinates**. There are three pieces to a library's coordinates, which act as a unique identifier for a particular version of that library, and help your build system (like Gradle or Maven) locate it.

- **Group ID** - The group ID usually represents the organization that produces the library. It often uses the reverse domain name of the organization or one of its websites. For example, the website for the Ktor HTTP library is http://ktor.io, so its group name is `io.ktor`.
- **Artifact ID** - The artifact ID identifies a specific module within a library. For example, the artifact ID for the core Ktor HTTP client is `ktor-client-core`.
- **Version** - Libraries change over time, and whenever that happens, they get new version numbers. There are a variety of ways that version numbers can be represented, but a major-minor-patch version number is very common. For example, a library with version `2.5.0` means that it's the second major version of that library, with the fifth minor revision, and no additional patches.

You can usually find the latest coordinates of a library on its website, especially if it has a "Getting Started" section. Alternatively, if the library's code is open source, you can usually find them in the `README.md` file for the project.

Finally, libraries are stored on servers called **artifact repositories**. Most Kotlin and JVM libraries are stored in a repository known as *Maven Central*. However, some are hosted on other servers. For example, Google has its own artifact repository. If you need a cutting-edge version, you might need to add the developer's repository that hosts development or pre-release builds. And if you're trying to add a library that's not publicly available—such as libraries that are private to the company you work for—you'll need to tell your build tool where the repository is.

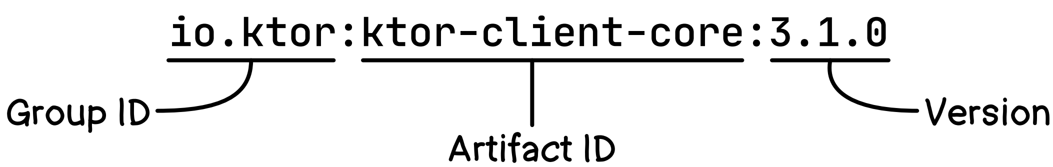
Once you've got the coordinates, you just need to add them to the build script. The build script looks different, depending on whether you're using Gradle or Maven. We'll start with Gradle.

## Adding Dependencies to a Gradle Project

Adding dependencies to a Gradle project is easy. Just open the **`build.gradle.kts`** file and look for a block of code that says **`dependencies`**. If it doesn't already exist, you can add it. Here's an example.

```
dependencies {
    implementation("org.jetbrains.kotlinx:kotlinx-coroutines-core:1.10.1")
    implementation("io.ktor:ktor-client-core:3.1.0")
    implementation("io.ktor:ktor-client-cio:3.1.0")
}
```

Inside that block, you can add a call to **`implementation()`** for each library that you want to include as a dependency. Its string argument represents the coordinates of the library, with each component of the coordinates separated with a colon.




If a library isn't available in Maven Central, you'll need to add its repository to your build script. In the same file, you'll probably see a **`repositories`** block, like this.

```
repositories {
    mavenCentral()
}
```

Adding a dependency on Google's artifact repository is easy because Gradle includes a function for it.

```
repositories {
    mavenCentral()
    google()
}
```

For other repositories, you'll need a URL, which you can just add like this.

```
repositories {
    mavenCentral()
    maven(url = "https://example.com/")
}
```

Whenever you update a **`build.gradle.kts`** file, you'll need to tell the IDE to update. In IntelliJ IDEA, look for a button with the Gradle elephant icon that appears in the top right corner. Alternatively, you can open the Gradle tool window by going to **View** > **Tool Windows** > **Gradle** and clicking the **Sync All Gradle Projects** button. Once that's done, you'll be ready to use the dependency in your project!

## Adding Dependencies to a Maven Project

Maven build files are named **`pom.xml`**. Instead of editing a build file written in Kotlin, as we do for Gradle, we'll need to edit an XML file. But the core concepts are the same.

Dependencies are added inside a **`<dependencies>`** block. For each dependency, you'll add a **`<dependency>`** tag. Unlike Gradle, the coordinates of the library are kept in separate XML tags, so it looks like this.

```
<dependencies>
    <dependency>
        <groupId>io.ktor</groupId>
        <artifactId>ktor-client-core</artifactId>
        <version>3.1.0</version>
    </dependency>
</dependencies>
```

Adding a repository is also straightforward. Just look for the **`<repositories>`** block, and add a new **`<repository>`** to it.

```
<repositories>
    <repository>
        <id>someArtifactRepository</id>
        <url>https://example.com/</url>
    </repository>
</repositories>
```

Just like with Gradle, any time you make a change to a **`pom.xml`** file, you'll need to synchronize the project so that it can download the libraries. Look for a button with a maven icon in the top right corner of the IDE, or open the Maven tool window by going to **View** > **Tool Windows** > **Maven** and hit the **Sync/Reload All Maven Projects** button.

## Summary

You're ready to add libraries to your projects. Whether you use Gradle or Maven, dependencies are an essential part of almost every Kotlin project, so it's important to know how to include them. Throughout most of this book, you won't need to add any dependencies, because we depend almost exclusively on Kotlin's standard library, which is added by default when you create your project. In Chapter 20, however, we also need to depend on the `kotlinx.coroutines` library. You can find the latest coordinates for that library at its website: https://github.com/Kotlin/kotlinx.coroutines.

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# Learn Kotlin programming the fun way!

With oodles of illustrations and concrete explanations, this book steps through Kotlin concepts one at a time to help you build a solid mental model of the language. Here's a sample of the fun topics you'll explore throughout this book:

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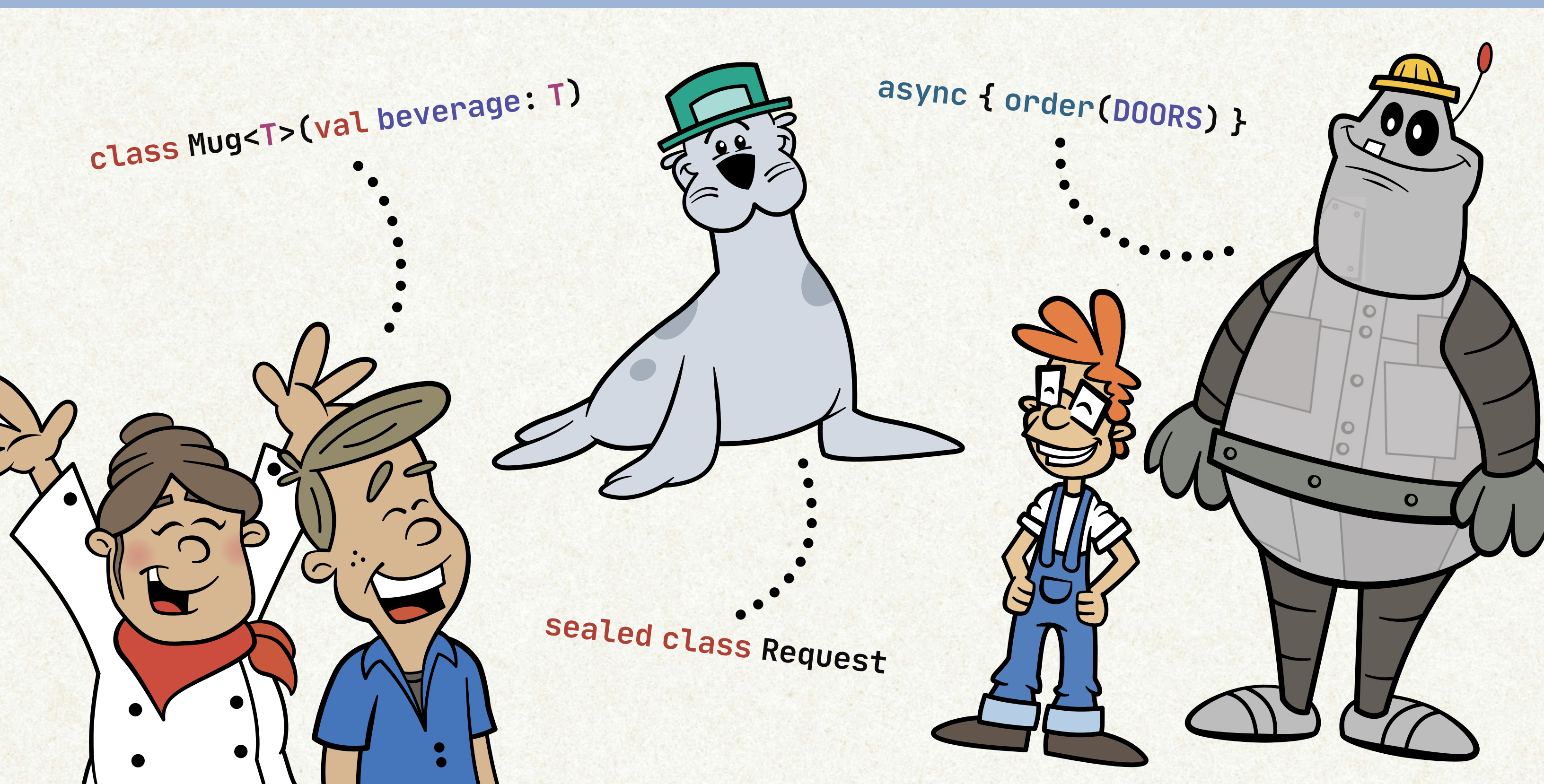
- Collection Processing
- Extension Functions
- Scope Functions
- Destructuring
- Sealed Types
- Generics and Variance
- Coroutines
- And lots more!

Whether you're brand new to the language or just looking to fill in some knowledge gaps, *Kotlin: An Illustrated Guide* is for you!




Dave Leeds has over 25 years of experience as a software developer, and has been writing about Kotlin—and drawing cartoons about it—since 2017.

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