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18

Patterns and Matching

Patterns are a special syntax in Rust for matching against the structure of types, both complex and simple. Using patterns in conjunction with match expressions and other constructs gives you more control over a program’s control flow. A pattern consists of some combination of the following:

Literals

Destructured arrays, enums, structs, or tuples

Variables

Wildcards

Placeholders

These components describe the shape of the data we’re working with, which we then match against values to determine whether our program has the correct data to continue running a particular piece of code.

To use a pattern, we compare it to some value. If the pattern matches the value, we use the value parts in our code. Recall the match expressions in Chapter 6 that used patterns, such as the coin sorting machine example. If the value fits the shape of the pattern, we can use the named pieces. If it doesn’t, the code associated with the pattern won’t run.

prod: check xref

This chapter is a reference on all things related to patterns. We’ll cover the valid places to use patterns, the difference between refutable and irrefutable patterns, and the different kinds of pattern syntax that you might see. By the end of the chapter, you’ll know how to use patterns to express many concepts in a clear way.

All the Places Patterns Can Be Used

Patterns pop up in a number of places in Rust, and you’ve been using them a lot without realizing it! This section provides you with a reference to all the places where patterns are valid.

match Arms

As discussed in Chapter 6, we use patterns in the arms of match expressions. Formally, match expressions are defined as the keyword match, a value to match on, and one or more match arms that consist of a pattern and an expression to run if the value matches that arm’s pattern, like this:

prod: check xref

match VALUE {

PATTERN => EXPRESSION,

PATTERN => EXPRESSION,

PATTERN => EXPRESSION,

}

One requirement for match expressions is that they need to be exhaustive in the sense that all possibilities for the value in the match expression must be accounted for. One way to ensure you’ve covered every possibility is to have a catchall pattern for the last arm: for example, a variable name matching any value can never fail and thus covers every remaining case.

A particular pattern \_ will match anything, but it never binds to a variable, so it’s often used in the last match arm. The \_ pattern can be useful when you want to ignore any value not specified, for example. We’ll cover the \_ pattern in more detail in the “Ignoring Values in a Pattern” section on page XX.

prod: check and fill xref (this chapter)

Conditional if let Expressions

In Chapter 6 we discussed how to use if let expressions mainly as a shorter way to write the equivalent of a match that only matches one case. Optionally, if let can have a corresponding else containing code to run if the pattern in the if let doesn’t match.

prod: check xref

Listing 18-1 shows that it’s also possible to mix and match if let, else if, and else if let expressions. Doing so gives us more flexibility than a match expression in which we can only express one value to compare with the patterns. Also, the conditions in a series of if let, else if, else if let arms aren’t required to relate to each other.

The code in Listing 18-1 shows a series of checks for several different conditions that decide what the background color should be. For this example, we’ve created variables with hardcoded values that a real program might receive from user input.

If the user specifies a favorite color, that color is the background color. If today is Tuesday, the background color will be green. If the user specifies their age as a string and we can parse it as a number successfully, the color is either purple or orange depending on the value of the number. If none of these conditions apply, the background color will be blue:

src/main.rs

fn main() {

let favorite\_color: Option<&str> = None;

let is\_tuesday = false;

let age: Result<u8, \_> = "34".parse();

if let Some(color) = favorite\_color {

println!("Using your favorite color, {}, as the background", color);

} else if is\_tuesday {

println!("Tuesday is green day!");

} else if let Ok(age) = age {

if age > 30 {

println!("Using purple as the background color");

} else {

println!("Using orange as the background color");

}

} else {

println!("Using blue as the background color");

}

}

Listing 18-1: Mixing if let, else if, else if let, and else

This conditional structure lets us support complex requirements. With the hardcoded values we have here, this example will print Using purple as the background color.

You can see that if let can also introduce shadowed variables in the same way that match arms can: the line if let Ok(age) = age introduces a new shadowed age variable that contains the value inside the Ok variant. This means we need to place the if age > 30 condition within that block: we can’t combine these two conditions into if let Ok(age) = age && age > 30. The shadowed age we want to compare to 30 isn’t valid until the new scope starts with the curly bracket.

The downside of using if let expressions is that the compiler doesn’t check exhaustiveness, whereas with match expressions it does. If we omitted the last else block and therefore missed handling some cases, the compiler would not alert us to the possible logic bug.

while let Conditional Loops

Similar in construction to if let, the while let conditional loop allows a while loop to run for as long as a pattern continues to match. The example in Listing 18-2 shows a while let loop that uses a vector as a stack and prints out the values in the vector in the opposite order in which they were pushed:

let mut stack = Vec::new();

stack.push(1);

stack.push(2);

stack.push(3);

while let Some(top) = stack.pop() {

println!("{}", top);

}

Listing 18-2: Using a while let loop to print values for as long as stack.pop() returns Some

This example prints 3, 2, and then 1. The pop method takes the last element out of the vector and returns Some(value). If the vector is empty, pop returns None. The while loop continues running the code in its block as long as pop returns Some. When pop returns None, the loop stops. We can use while let to pop every element off our stack.

for Loops

In Chapter 3 we mentioned that the for loop is the most common loop construction in Rust code, but we haven’t yet discussed the pattern that for takes. In a for loop, the pattern is the value that directly follows the keyword for, so in for x in y the x is the pattern.

prod: confirm xref

Listing 18-3 demonstrates how to use a pattern in a for loop to destructure, or break apart, a tuple as part of the for loop:

let v = vec!['a', 'b', 'c'];

for (index, value) in v.iter().enumerate() {

println!("{} is at index {}", value, index);

}

Listing 18-3: Using a pattern in a for loop to destructure a tuple

The code in Listing 18-3 will print the following:

a is at index 0

b is at index 1

c is at index 2

We use the enumerate method to adapt an iterator to produce a value and that value’s index in the iterator, placed into a tuple. The first call to enumerate produces the tuple (0, 'a'). When this value is matched to the pattern (index, value), index will be 0 and value will be 'a', printing the first line of the output.

let Statements

Prior to this chapter, we had only explicitly discussed using patterns with match and if let, but in fact, we’ve used patterns in other places as well, including in let statements. For example, consider this straightforward variable assignment with let:

let x = 5;

Throughout this book, we’ve used let like this hundreds of times, and although you might not have realized it, you were using patterns! More formally, a let statement looks like this:

let PATTERN = EXPRESSION;

In statements like let x = 5; with a variable name in the PATTERN slot, the variable name is just a particularly simple form of a pattern. Rust compares the expression against the pattern and assigns any names it finds. So in the let x = 5; example, x is a pattern that means “bind what matches here to the variable x.” Because the name x is the whole pattern, this pattern effectively means “bind everything to the variable x, whatever the value is.”

To see the pattern matching aspect of let more clearly, consider Listing 18-4, which uses a pattern with let to destructure a tuple:

let (x, y, z) = (1, 2, 3);

Listing 18-4: Using a pattern to destructure a tuple and create three variables at once

Here, we match a tuple against a pattern. Rust compares the value (1, 2, 3) to the pattern (x, y, z) and sees that the value matches the pattern, so Rust binds 1 to x, 2 to y, and 3 to z. You can think of this tuple pattern as nesting three individual variable patterns inside it.

If the number of elements in the pattern doesn’t match the number of elements in the tuple, the overall type won’t match and we’ll get a compiler error. For example, Listing 18-5 shows an attempt to destructure a tuple with three elements into two variables, which won’t work:

let (x, y) = (1, 2, 3);

Listing 18-5: Incorrectly constructing a pattern whose variables don’t match the number of elements in the tuple

Attempting to compile this code results in this type error:

error[E0308]: mismatched types

--> src/main.rs:2:9

|

2 | let (x, y) = (1, 2, 3);

| ^^^^^^ expected a tuple with 3 elements, found one with 2 elements

|

= note: expected type `({integer}, {integer}, {integer})`

found type `(\_, \_)`

If we wanted to ignore one or more of the values in the tuple, we could use \_ or .. as you’ll see in the “Ignoring Values in a Pattern” section on page XX. If the problem is that we have too many variables in the pattern, the solution is to make the types match by removing variables so the number of variables equals the number of elements in the tuple.

prod: check & fill xref (this chapter)

Function Parameters

Function parameters can also be patterns. The code in Listing 18-6, which declares a function named foo that takes one parameter named x of type i32, should by now look familiar:

fn foo(x: i32) {

// code goes here

}

Listing 18-6: A function signature uses patterns in the parameters

The x part is a pattern! As we did with let, we could match a tuple in a function’s arguments to the pattern. Listing 18-7 splits the values in a tuple as we pass it to a function:

src/main.rs

fn print\_coordinates(&(x, y): &(i32, i32)) {

println!("Current location: ({}, {})", x, y);

}

fn main() {

let point = (3, 5);

print\_coordinates(&point);

}

Listing 18-7: A function with parameters that destructure a tuple

This code prints Current location: (3, 5). The values &(3, 5) match the pattern &(x, y), so x is the value 3 and y is the value 5.

We can also use patterns in closure parameter lists in the same way as in function parameter lists, because closures are similar to functions, as discussed in Chapter 13.

prod: confirm xref

At this point, you’ve seen several ways of using patterns, but patterns don’t work the same in every place we can use them. In some places, the patterns must be irrefutable, meaning they must match any value provided. In other circumstances, they can be refutable. Let’s discuss these two concepts next.

Refutability: Whether a Pattern Might Fail to Match

Patterns come in two forms: refutable and irrefutable. Patterns that will match for any possible value passed are irrefutable. An example would be x in the statement let x = 5; because x matches anything and therefore cannot fail to match. Patterns that can fail to match for some possible value are refutable. An example would be Some(x) in the expression if let Some(x) = a\_value; if the value in a\_value variable is None rather than Some, the Some(x) pattern would not match.

Function parameters, let statements, and for loops can only accept irrefutable patterns, because the program cannot do anything meaningful when values don’t match. The if let and while let expressions only accept refutable patterns, because by definition they’re intended to handle possible failure: the functionality of a conditional is in its ability to perform differently depending on success or failure.

In general, you shouldn’t have to worry about the distinction between refutable and irrefutable patterns; however, you do need to be familiar with the concept of refutability so you can respond when you see it in an error message. In those cases, you’ll need to change either the pattern or the construct you’re using the pattern with, depending on the intended behavior of the code.

Let’s look at an example of what happens when we try to use a refutable pattern where Rust requires an irrefutable pattern and vice versa. Listing 18-8 shows a let statement, but for the pattern we’ve specified Some(x), a refutable pattern. As you might expect, this code will error:

let Some(x) = some\_option\_value;

Listing 18-8: Attempting to use a refutable pattern with let

If some\_option\_value was a None value, it would fail to match the pattern Some(x), meaning the pattern is refutable. However, the let statement can only accept an irrefutable pattern because there is nothing valid the code can do with a None value. At compile time, Rust will complain that we’ve tried to use a refutable pattern where an irrefutable pattern is required:

error[E0005]: refutable pattern in local binding: `None` not covered

-->

|

3 | let Some(x) = some\_option\_value;

| ^^^^^^^ pattern `None` not covered

Because we didn’t cover (and couldn’t cover!) every valid value with the pattern Some(x), Rust rightfully produces a compiler error.

To fix the problem where we have a refutable pattern where an irrefutable pattern is needed, we can change the code that uses the pattern: instead of using let, we can use if let. Then if the pattern doesn’t match, the code will just skip the code in the curly brackets, giving it a way to continue validly. Listing 18-9 shows how to fix the code in Listing 18-8:

if let Some(x) = some\_option\_value {

println!("{}", x);

}

Listing 18-9: Using if let and a block with refutable patterns instead of let

We’ve given the code an out! This code is perfectly valid, although it means we cannot use an irrefutable pattern without receiving an error. If we give if let a pattern that will always match, such as x, as shown in Listing 18-10, it will error:

if let x = 5 {

println!("{}", x);

};

Listing 18-10: Attempting to use an irrefutable pattern with if let

Rust complains that it doesn’t make sense to use if let with an irrefutable pattern:

error[E0162]: irrefutable if-let pattern

--> <anon>:2:8

|

2 | if let x = 5 {

| ^ irrefutable pattern

For this reason, match arms must use refutable patterns, except for the last arm, which should match any remaining values with an irrefutable pattern. Rust allows us to use an irrefutable pattern in a match with only one arm, but this syntax isn’t particularly useful and could be replaced with a simpler let statement.

Now that you know where to use patterns and the difference between refutable and irrefutable patterns, let’s cover all the syntax we can use to create patterns.

All the Pattern Syntax

Throughout the book, you’ve seen examples of many different kinds of patterns. In this section, we gather all the syntax valid in patterns and discuss why you might want to use each of them.

Matching Literals

As you saw in Chapter 6, you can match patterns against literals directly. The following code gives some examples:

prod: confirm xref

let x = 1;

match x {

1 => println!("one"),

2 => println!("two"),

3 => println!("three"),

\_ => println!("anything"),

}

This code prints one because the value in x is 1. This syntax is useful when you want your code to take an action if it gets a particular concrete value.

Matching Named Variables

Named variables are irrefutable patterns that match any value, and we’ve used them many times in the book. However, there is a complication when you use named variables in match expressions. Because match starts a new scope, variables declared as part of a pattern inside the match expression will shadow those with the same name outside the match construct, as is the case with all variables. In Listing 18-11, we declare a variable named x with the value Some(5) and a variable y with the value 10. We then create a match expression on the value x. Look at the patterns in the match arms and println! at the end, and try to figure out what the code will print before running this code or reading further:

src/main.rs

fn main() {

let x = Some(5);

let y = 10;

match x {

Some(50) => println!("Got 50"),

Some(y) => println!("Matched, y = {:?}", y),

\_ => println!("Default case, x = {:?}", x),

}

println!("at the end: x = {:?}, y = {:?}", x, y);

}

Listing 18-11: A match expression with an arm that introduces a shadowed variable y

Let’s walk through what happens when the match expression runs. The pattern in the first match arm doesn’t match the defined value of x, so the code continues.

The pattern in the second match arm introduces a new variable named y that will match any value inside a Some value. Because we’re in a new scope inside the match expression, this is a new y variable, not the y we declared at the beginning with the value 10. This new y binding will match any value inside a Some, which is what we have in x. Therefore, this new y binds to the inner value of the Some in x. That value is 5, so the expression for that arm executes and prints Matched, y = 5.

If x had been a None value instead of Some(5), the patterns in the first two arms wouldn’t have matched, so the value would have matched to the underscore. We didn’t introduce the x variable in the pattern of the underscore arm, so the x in the expression is still the outer x that hasn’t been shadowed. In this hypothetical case, the match would print Default case, x = None.

When the match expression is done, its scope ends, and so does the scope of the inner y. The last println! produces at the end: x = Some(5), y = 10.

To create a match expression that compares the values of the outer x and y, rather than introducing a shadowed variable, we would need to use a match guard conditional instead. We’ll talk about match guards later in the “Extra Conditionals with Match Guards” section on page XX.

prod: check & fill xref (this chapter)

Multiple Patterns

In match expressions, you can match multiple patterns using the | syntax, which means or. For example, the following code matches the value of x against the match arms, the first of which has an or option, meaning if the value of x matches either of the values in that arm, that arm’s code will run:

let x = 1;

match x {

1 | 2 => println!("one or two"),

3 => println!("three"),

\_ => println!("anything"),

}

This code prints one or two.

Matching Ranges of Values with ...

The ... syntax allows us to match to an inclusive range of values. In the following code, when a pattern matches any of the values within the range, that arm will execute:

let x = 5;

match x {

1 ... 5 => println!("one through five"),

\_ => println!("something else"),

}

If x is 1, 2, 3, 4, or 5, the first arm will match. This syntax is more convenient than using the | operator to express the same idea; instead of 1 ... 5, we would have to specify 1 | 2 | 3 | 4 | 5 if we used |. Specifying a range is much shorter, especially if we want to match, say, any number between 1 and 1,000!

Ranges are only allowed with numeric values or char values, because the compiler checks that the range isn’t empty at compile time. The only types for which Rust can tell if a range is empty or not are char and numeric values.

Here is an example using ranges of char values:

let x = 'c';

match x {

'a' ... 'j' => println!("early ASCII letter"),

'k' ... 'z' => println!("late ASCII letter"),

\_ => println!("something else"),

}

Rust can tell that c is within the first pattern’s range and prints early ASCII letter.

Destructuring to Break Apart Values

We can also use patterns to destructure structs, enums, tuples, and references to use different parts of these values. Let’s walk through each value.

Destructuring Structs

Listing 18-12 shows a Point struct with two fields, x and y, that we can break apart using a pattern with a let statement:

src/main.rs

struct Point {

x: i32,

y: i32,

}

fn main() {

let p = Point { x: 0, y: 7 };

let Point { x: a, y: b } = p;

assert\_eq!(0, a);

assert\_eq!(7, b);

}

Listing 18-12: Destructuring a struct’s fields into separate variables

This code creates the variables a and b that match the values of the x and y fields of the p variable. This example shows that the names of the variables in the pattern don’t have to match the field names of the struct. But it’s common to want the variable names to match the field names to make it easier to remember which variables came from which fields.

Because having variable names match the fields is common and because writing let Point { x: x, y: y } = p; contains a lot of duplication, there is a shorthand for patterns that match struct fields: you only need to list the name of the struct field, and the variables created from the pattern will have the same names. Listing 18-13 shows code that behaves in the same way as the code in Listing 18-12, but the variables created in the let pattern are x and y instead of a and b:

src/main.rs

struct Point {

x: i32,

y: i32,

}

fn main() {

let p = Point { x: 0, y: 7 };

let Point { x, y } = p;

assert\_eq!(0, x);

assert\_eq!(7, y);

}

Listing 18-13: Destructuring struct fields using struct field shorthand

This code creates the variables x and y that match the x and y fields of the p variable. The outcome is that the variables x and y contain the values from the p struct.

We can also destructure with literal values as part of the struct pattern rather than creating variables for all the fields. Doing so allows us to test some of the fields for particular values while creating variables to destructure the other fields.

Listing 18-14 shows a match expression that separates Point values into three cases: points that lie directly on the x axis (which is true when y = 0), on the y axis (x = 0), or neither:

src/main.rs

fn main() {

let p = Point { x: 0, y: 7 };

match p {

Point { x, y: 0 } => println!("On the x axis at {}", x),

Point { x: 0, y } => println!("On the y axis at {}", y),

Point { x, y } => println!("On neither axis: ({}, {})", x, y),

}

}

Listing 18-14: Destructuring and matching literal values in one pattern

The first arm will match any point that lies on the x axis by specifying that the y field matches if its value matches the literal 0. The pattern still creates an x variable that we can use in the code for this arm.

Similarly, the second arm matches any point on the y axis by specifying that the x field matches if its value is 0 and creates a variable y for the value of the y field. The third arm doesn’t specify any literals, so it matches any other Point and creates variables for both the x and y fields.

In this example, the value p matches the second arm by virtue of x containing a 0, so this code will print On the y axis at 7.

Destructuring Enums

We’ve destructured enums earlier in this book, for example, when we destructured Option<i32> in Listing 6-5 in Chapter 6. One detail we haven’t mentioned explicitly is that the pattern to destructure an enum should correspond to the way the data stored within the enum is defined. As an example, in Listing 18-15 we use the Message enum from Listing 6-2 and write a match with patterns that will destructure each inner value:

prod: check xrefs

src/main.rs

enum Message {

Quit,

Move { x: i32, y: i32 },

Write(String),

ChangeColor(i32, i32, i32),

}

fn main() {

let msg = Message::ChangeColor(0, 160, 255);

match msg {

Message::Quit => {

println!("The Quit variant has no data to destructure.")

},

Message::Move { x, y } => {

println!(

"Move in the x direction {} and in the y direction {}",

x,

y

);

}

Message::Write(text) => println!("Text message: {}", text),

Message::ChangeColor(r, g, b) => {

println!(

"Change the color to red {}, green {}, and blue {}",

r,

g,

b

)

}

}

}

Listing 18-15: Destructuring enum variants that hold different kinds of values

This code will print Change the color to red 0, green 160, and blue 255. Try changing the value of msg to see the code from the other arms run.

For enum variants without any data, like Message::Quit, we can’t destructure the value any further. We can only match on the literal Message::Quit value, and no variables are in that pattern.

For struct-like enum variants, such as Message::Move, we can use a pattern similar to the pattern we specify to match structs. After the variant name, we place curly brackets and then list the fields with variables so we break apart the pieces to use in the code for this arm. Here we use the shorthand form as we did in Listing 18-13.

For tuple-like enum variants, like Message::Write that holds a tuple with one element and Message::ChangeColor that holds a tuple with three elements, the pattern is similar to the pattern we specify to match tuples. The number of variables in the pattern must match the number of elements in the variant we’re matching.

Destructuring References

When the value we’re matching to our pattern contains a reference, we need to destructure the reference from the value, which we can do by specifying a & in the pattern. Doing so lets us get a variable holding the value that the reference points to rather than getting a variable that holds the reference. This technique is especially useful in closures where we have iterators that iterate over references, but we want to use the values in the closure rather than the references.

The example in Listing 18-16 iterates over references to Point instances in a vector, and destructures the reference and the struct so we can perform calculations on the x and y values easily:

let points = vec![

Point { x: 0, y: 0 },

Point { x: 1, y: 5 },

Point { x: 10, y: -3 },

];

let sum\_of\_squares: i32 = points

.iter()

.map(|&Point { x, y }| x \* x + y \* y)

.sum();

Listing 18-16: Destructuring a reference to a struct into the struct field values

This code gives us the variable sum\_of\_squares holding the value 135, which is the result of squaring the x value and the y value, adding those together, and then adding the result for each Point in the points vector to get one number.

If we had not included the & in &Point { x, y } we’d get a type mismatch error, because iter would then iterate over references to the items in the vector rather than the actual values. The error would look like this:

error[E0308]: mismatched types

-->

|

14 | .map(|Point { x, y }| x \* x + y \* y)

| ^^^^^^^^^^^^ expected &Point, found struct `Point`

|

= note: expected type `&Point`

found type `Point`

This error indicates that Rust was expecting our closure to match &Point, but we tried to match directly to a Point value, not a reference to a Point.

Destructuring Structs and Tuples

We can mix, match, and nest destructuring patterns in even more complex ways. The following example shows a complicated destructure where we nest structs and tuples inside a tuple, and destructure all the primitive values out:

let ((feet, inches), Point {x, y}) = ((3, 10), Point { x: 3, y: -10 });

This code lets us break complex types into their component parts so we can use the values we’re interested in separately.

Destructuring with patterns is a convenient way to use pieces of values, such as the value from each field in a struct, separately from each other.

Ignoring Values in a Pattern

You’ve seen that it’s sometimes useful to ignore values in a pattern, such as in the last arm of a match, to get a catchall that doesn’t actually do anything but does account for all remaining possible values. There are a few ways to ignore entire values or parts of values in a pattern: using the \_ pattern (which you’ve seen), using the \_ pattern within another pattern, using a name that starts with an underscore, or using .. to ignore remaining parts of a value. Let’s explore how and why to use each of these patterns.

Ignoring an Entire Value with \_

We’ve used the underscore \_ as a wildcard pattern that will match any value but not bind to the value. Although the underscore \_ pattern is especially useful as the last arm in a match expression, we can use it in any pattern, including function parameters, as shown in Listing 18-17:

src/main.rs

fn foo(\_: i32, y: i32) {

println!("This code only uses the y parameter: {}", y);

}

fn main() {

foo(3, 4);

}

Listing 18-17: Using \_ in a function signature

This code will completely ignore the value passed as the first argument, 3, and will print This code only uses the y parameter: 4.

In most cases when you no longer need a particular function parameter, you would change the signature so it doesn’t include the unused parameter. Ignoring a function parameter can be especially useful in some cases: for example, when implementing a trait when you need a certain type signature but the function body in your implementation doesn’t need one of the parameters. The compiler will then not warn about unused function parameters, as it would if you used a name instead.

Ignoring Parts of a Value with a Nested \_

We can also use \_ inside another pattern to ignore just part of a value: for example, when we only want to test for part of a value but have no use for the other parts in the corresponding code we want to run. Listing 18-18 shows code responsible for managing a setting’s value. The business requirements are that the user should not be allowed to overwrite an existing customization of a setting but can unset the setting and can give the setting a value if it is currently unset.

let mut setting\_value = Some(5);

let new\_setting\_value = Some(10);

match (setting\_value, new\_setting\_value) {

(Some(\_), Some(\_)) => {

println!("Can't overwrite an existing customized value");

}

\_ => {

setting\_value = new\_setting\_value;

}

}

println!("setting is {:?}", setting\_value);

Listing 18-18: Using an underscore within patterns that match Some variants when we don’t need to use the value inside the Some

This code will print Can't overwrite an existing customized value and then setting is Some(5). In the first match arm, we don’t need to match on or use the values inside either Some variant, but we do need to test for the case when setting\_value and new\_setting\_value are the Some variant. In that case, we print why we’re not changing setting\_value, and it doesn’t get changed.

In all other cases (if either setting\_value or new\_setting\_value are None) expressed by the \_ pattern in the second arm, we want to allow new\_setting\_value to become setting\_value.

We can also use underscores in multiple places within one pattern to ignore particular values. Listing 18-19 shows an example of ignoring the second and fourth values in a tuple of five items:

let numbers = (2, 4, 8, 16, 32);

match numbers {

(first, \_, third, \_, fifth) => {

println!("Some numbers: {}, {}, {}", first, third, fifth)

},

}

Listing 18-19: Ignoring multiple parts of a tuple

This code will print Some numbers: 2, 8, 32, and the values 4 and 16 will be ignored.

Ignoring an Unused Variable by Starting Its Name with an Underscore

If you create a variable but don’t use it anywhere, Rust will usually issue a warning because that could be a bug. But sometimes it’s useful to create a variable you won’t use yet, such as when you’re prototyping or just starting a project. In this situation, you can tell Rust not to warn you about the unused variable by starting the name of the variable with an underscore. In Listing 18-20, we create two unused variables, but when we run this code, we should only get a warning about one of them:

src/main.rs

fn main() {

let \_x = 5;

let y = 10;

}

Listing 18-20: Starting a variable name with an underscore to avoid getting unused variable warnings

Here we get a warning about not using the variable y, but we don’t get a warning about not using the variable preceded by the underscore.

Note that there is a subtle difference between using only \_ and using a name that starts with an underscore. The syntax \_x still binds the value to the variable, whereas \_ doesn’t bind at all. To show a case where this distinction matters, Listing 18-21 will provide us with an error:

let s = Some(String::from("Hello!"));

if let Some(\_s) = s {

println!("found a string");

}

println!("{:?}", s);

Listing 18-21: An unused variable starting with an underscore still binds the value, which might take ownership of the value

We’ll receive an error because the s value will still be moved into \_s, which prevents us from using s again. However, using the underscore by itself doesn’t ever bind to the value. Listing 18-22 will compile without any errors because s doesn’t get moved into \_:

let s = Some(String::from("Hello!"));

if let Some(\_) = s {

println!("found a string");

}

println!("{:?}", s);

Listing 18-22: Using an underscore does not bind the value

This code works just fine because we never bind s to anything; it isn’t moved.

Ignoring Remaining Parts of a Value with ..

With values that have many parts, we can use the .. syntax to use only a few parts and ignore the rest, and avoid having to list underscores for each ignored value. The .. pattern ignores any parts of a value that we haven’t explicitly matched in the rest of the pattern. In Listing 18-23, we have a Point struct that holds a coordinate in three-dimensional space. In the match expression, we want to operate only on the x coordinate and ignore the values in the y and z fields:

struct Point {

x: i32,

y: i32,

z: i32,

}

let origin = Point { x: 0, y: 0, z: 0 };

match origin {

Point { x, .. } => println!("x is {}", x),

}

Listing 18-23: Ignoring all fields of a Point except for x by using ..

We list the x value, and then just include the .. pattern. This is quicker than having to list y: \_ and z: \_, particularly when we’re working with structs that have lots of fields in situations where only one or two fields are relevant.

The syntax .. will expand to as many values as it needs to be. Listing 18-24 shows how to use .. with a tuple:

src/main.rs

fn main() {

let numbers = (2, 4, 8, 16, 32);

match numbers {

(first, .., last) => {

println!("Some numbers: {}, {}", first, last);

},

}

}

Listing 18-24: Matching only the first and last values in a tuple and ignoring all other values

In this code, the first and last value are matched with first and last. The .. will match and ignore everything in the middle.

However, using .. must be unambiguous. If it is unclear which values are intended for matching and which should be ignored, Rust will error. Listing 18-25 shows an example of using .. ambiguously, so it will not compile:

src/main.rs

fn main() {

let numbers = (2, 4, 8, 16, 32);

match numbers {

(.., second, ..) => {

println!("Some numbers: {}", second)

},

}

}

Listing 18-25: An attempt to use .. in an ambiguous way

When we compile this example, we get this error:

error: `..` can only be used once per tuple or tuple struct pattern

--> src/main.rs:5:22

|

5 | (.., second, ..) => {

| ^^

It’s impossible for Rust to determine how many values in the tuple to ignore before matching a value with second, and then how many further values to ignore thereafter. This code could mean that we want to ignore 2, bind second to 4, and then ignore 8, 16, and 32; or that we want to ignore 2 and 4, bind second to 8, and then ignore 16 and 32; and so forth. The variable name second doesn’t mean anything special to Rust, so we get a compiler error because using .. in two places like this is ambiguous.

ref and ref mut to Create References in Patterns

Let’s look at using ref to make references so ownership of the values isn’t moved to variables in the pattern. Usually, when you match against a pattern, the variables introduced by the pattern are bound to a value. Rust’s ownership rules mean the value will be moved into the match or wherever you’re using the pattern. Listing 18-26 shows an example of a match that has a pattern with a variable and then usage of the entire value in the println! statement later, after the match. This code will fail to compile because ownership of part of the robot\_name value is transferred to the name variable in the pattern of the first match arm:

let robot\_name = Some(String::from("Bors"));

match robot\_name {

Some(name) => println!("Found a name: {}", name),

None => (),

}

println!("robot\_name is: {:?}", robot\_name);

Listing 18-26: Creating a variable in a match arm pattern takes ownership of the value

Because ownership of part of robot\_name has been moved to name, we can no longer use robot\_name in the println! after the match because robot\_name no longer has ownership.

To fix this code, we want to make the Some(name) pattern borrow that part of robot\_name rather than taking ownership. You’ve already seen that, outside of patterns, the way to borrow a value is to create a reference using &, so you might think the solution is changing Some(name) to Some(&name).

However, as you saw in the section “Destructuring to Break Apart Values” on page XX, the syntax & in patterns does not create a reference but matches an existing reference in the value. Because & already has that meaning in patterns, we can’t use & to create a reference in a pattern.

Instead, to create a reference in a pattern, we use the ref keyword before the new variable, as shown in Listing 18-27:

prod: check & fill xref (this chapter)

let robot\_name = Some(String::from("Bors"));

match robot\_name {

Some(ref name) => println!("Found a name: {}", name),

None => (),

}

println!("robot\_name is: {:?}", robot\_name);

Listing 18-27: Creating a reference so a pattern variable does not take ownership of a value

This example will compile because the value in the Some variant in robot\_name is not moved into the match; the match only took a reference to the data in robot\_name rather than moving it.

To create a mutable reference so we’re able to mutate a value matched in a pattern, we use ref mut instead of &mut. The reason is, again, that in patterns, the latter is for matching existing mutable references, not creating new ones. Listing 18-28 shows an example of a pattern creating a mutable reference:

let mut robot\_name = Some(String::from("Bors"));

match robot\_name {

Some(ref mut name) => \*name = String::from("Another name"),

None => (),

}

println!("robot\_name is: {:?}", robot\_name);

Listing 18-28: Creating a mutable reference to a value as part of a pattern using ref mut

This example will compile and print robot\_name is: Some("Another name"). Because name is a mutable reference, we need to dereference within the match arm code using the \* operator to mutate the value.

Extra Conditionals with Match Guards

A match guard is an additional if condition specified after the pattern in a match arm that must also match, along with the pattern matching, for that arm to be chosen. Match guards are useful for expressing more complex ideas than a pattern alone allows.

The condition can use variables created in the pattern. Listing 18-29 shows a match where the first arm has the pattern Some(x) and also has a match guard of if x < 5:

let num = Some(4);

match num {

Some(x) if x < 5 => println!("less than five: {}", x),

Some(x) => println!("{}", x),

None => (),

}

Listing 18-29: Adding a match guard to a pattern

This example will print less than five: 4. When num is compared to the pattern in the first arm, it matches, because Some(4) matches Some(x). Then the match guard checks whether the value in x is less than 5, and because it is, the first arm is selected.

If num had been Some(10) instead, the match guard in the first arm would have been false because 10 is not less than 5. Rust would then go to the second arm, which would match because the second arm doesn’t have a match guard and therefore matches any Some variant.

There is no way to express the if x < 5 condition within a pattern, so the match guard gives us the ability to express this logic.

In Listing 18-11, we mentioned that we could use match guards to solve our pattern shadowing problem. Recall that a new variable was created inside the pattern in the match expression instead of using the variable outside the match. That new variable meant we couldn’t test against the value of the outer variable. Listing 18-30 shows how we can use a match guard to fix this problem:

src/main.rs

fn main() {

let x = Some(5);

let y = 10;

match x {

Some(50) => println!("Got 50"),

Some(n) if n == y => println!("Matched, n = {:?}", n),

\_ => println!("Default case, x = {:?}", x),

}

println!("at the end: x = {:?}, y = {:?}", x, y);

}

Listing 18-30: Using a match guard to test for equality with an outer variable

This code will now print Default case, x = Some(5). The pattern in the second match arm doesn’t introduce a new variable y that would shadow the outer y, meaning we can use the outer y in the match guard. Instead of specifying the pattern as Some(y), which would have shadowed the outer y, we specify Some(n). This creates a new variable n that doesn’t shadow anything because there is no n variable outside the match.

The match guard if n == y is not a pattern and therefore doesn’t introduce new variables. This y is the outer y rather than a new shadowed y, and we can look for a value that has the same value as the outer y by comparing n to y.

You can also use the or operator | in a match guard to specify multiple patterns; the match guard condition will apply to all the patterns. Listing 18-31 shows the precedence of combining a match guard with a pattern that uses |. The important part of this example is that the if y match guard applies to 4, 5, and 6, even though it might look like if y only applies to 6:

let x = 4;

let y = false;

match x {

4 | 5 | 6 if y => println!("yes"),

\_ => println!("no"),

}

Listing 18-31: Combining multiple patterns with a match guard

The match condition states that the arm only matches if the value of x is equal to 4, 5, or 6 and if y is true. When this code runs, the pattern of the first arm matches because x is 4, but the match guard if y is false, so the first arm is not chosen. The code moves on to the second arm, which does match, and this program prints no. The reason is that the if condition applies to the whole pattern 4 | 5 | 6, not only to the last value 6. In other words, the precedence of a match guard in relation to a pattern behaves like this:

(4 | 5 | 6) if y => ...

rather than this:

4 | 5 | (6 if y) => ...

After running the code, the precedence behavior is evident: if the match guard was only applied to the final value in the list of values specified using the | operator, the arm would have matched and the program would have printed yes.

@ Bindings

The at operator @ lets us create a variable that holds a value at the same time we’re testing that value to see whether it matches a pattern. Listing 18-32 shows an example where we want to test that a Message::Hello id field is within the range 3...7. But we also want to bind the value to the variable id\_variable so we can use it in the code associated with the arm. We could name this variable id, the same as the field, but for this example we’ll use a different name:

enum Message {

Hello { id: i32 },

}

let msg = Message::Hello { id: 5 };

match msg {

Message::Hello { id: id\_variable @ 3...7 } => {

println!("Found an id in range: {}", id\_variable)

},

Message::Hello { id: 10...12 } => {

println!("Found an id in another range")

},

Message::Hello { id } => {

println!("Found some other id: {}", id)

},

}

Listing 18-32: Using @ to bind to a value in a pattern while also testing it

This example will print Found an id in range: 5. By specifying id\_variable @ before the range 3...7, we’re capturing whatever value matched the range while also testing that the value matched the range pattern.

In the second arm where we only have a range specified in the pattern, the code associated with the arm doesn’t have a variable that contains the actual value of the id field. The id field’s value could have been 10, 11, or 12, but the code that goes with that pattern doesn’t know which it is. The pattern code isn’t able to use the value from the id field, because we haven’t saved the id value in a variable.

In the last arm where we’ve specified a variable without a range, we do have the value available to use in the arm’s code in a variable named id. The reason is that we’ve used the struct field shorthand syntax. But we haven’t applied any test to the value in the id field in this arm, like we did with the first two arms: any value would match this pattern.

Using @ lets us test a value and save it in a variable within one pattern.

Summary

Rust’s patterns are very useful in that they help distinguish between different kinds of data. When used in match expressions, Rust ensures your patterns cover every possible value, or your program won’t compile. Patterns in let statements and function parameters make those constructs more useful, enabling the destructuring of values into smaller parts at the same time as assigning to variables. We can create simple or complex patterns to suit our needs.

Next, for the penultimate chapter of the book, we’ll look at some advanced aspects of a variety of Rust’s features.