You Don't Know JS: Types & Grammar

Chapter 4: Coercion

Now that we much more fully understand JavaScript's types and values, we turn our attention to a very controversial topic: coercion.

As we mentioned in Chapter 1, the debates over whether coercion is a useful feature or a flaw in the design of the language (or somewhere in between!) have raged since day one. If you've read other popular books on JS, you know that the overwhelmingly prevalent *message* out there is that coercion is magical, evil, confusing, and just downright a bad idea.

In the same overall spirit of this book series, rather than running away from coercion because everyone else does, or because you get bitten by some quirk, I think you should run toward that which you don't understand and seek to *get it* more fully.

Our goal is to fully explore the pros and cons (yes, there *are* pros!) of coercion, so that you can make an informed decision on its appropriateness in your program.

Converting Values

Converting a value from one type to another is often called "type casting," when done explicitly, and "coercion" when done implicitly (forced by the rules of how a value is used).

Note: It may not be obvious, but JavaScript coercions always result in one of the scalar primitive (see Chapter 2) values, like `string`, `number`, or `boolean`. There is no coercion that results in a complex value like `object` or `function`. Chapter 3 covers "boxing," which wraps scalar primitive values in their `object` counterparts, but this is not really coercion in an accurate sense.
Another way these terms are often distinguished is as follows: "type casting" (or "type conversion") occur in statically typed languages at compile time, while "type coercion" is a runtime conversion for dynamically typed languages.

However, in JavaScript, most people refer to all these types of conversions as *coercion*, so the way I prefer to distinguish is to say "implicit coercion" vs. "explicit coercion."

The difference should be obvious: "explicit coercion" is when it is obvious from looking at the code that a type conversion is intentionally occurring, whereas "implicit coercion" is when the type conversion will occur as a less obvious side effect of some other intentional operation.

For example, consider these two approaches to coercion:

```
var a = 42;

var b = a + "";                    // implicit coercion

var c = String( a );     // explicit coercion
```

For `b`, the coercion that occurs happens implicitly, because the `+` operator combined with one of the operands being a `string` value (`""`) will insist on the operation being a `string` concatenation (adding two strings together), which *as a (hidden) side effect* will force the `42` value in `a` to be coerced to its `string` equivalent: `"42"`.
By contrast, the `String(..)` function makes it pretty obvious that it's explicitly taking the value in `a` and coercing it to a `string` representation.
Both approaches accomplish the same effect: `"42"` comes from `42`. But it's the *how* that is at the heart of the heated debates over JavaScript coercion.
Note: Technically, there's some nuanced behavioral difference here beyond the stylistic difference. We cover that in more detail later in the chapter, in the "Implicitly: Strings <--> Numbers" section.

The terms "explicit" and "implicit," or "obvious" and "hidden side effect," are *relative*.

If you know exactly what `a + ""` is doing and you're intentionally doing that to coerce to a `string`, you might feel the operation is sufficiently "explicit." Conversely, if you've never seen the `String(..)` function used for `string` coercion, its behavior might seem hidden enough as to feel "implicit" to you.
But we're having this discussion of "explicit" vs. "implicit" based on the likely opinions of an *average, reasonably informed, but not expert or JS specification devotee* developer. To whatever extent you do or do not find yourself fitting neatly in that bucket, you will need to adjust your perspective on our observations here accordingly.

Just remember: it's often rare that we write our code and are the only ones who ever read it. Even if you're an expert on all the ins and outs of JS, consider how a less experienced teammate of yours will feel when they read your code. Will it be "explicit" or "implicit" to them in the same way it is for you?

Abstract Value Operations

Before we can explore *explicit* vs *implicit* coercion, we need to learn the basic rules that govern how values *become* either a `string`, `number`, or `boolean`. The ES5 spec in section 9 defines several "abstract operations" (fancy spec-speak for "internal-only operation") with the rules of value conversion. We will specifically pay attention to: `ToString`, `ToNumber`, and `ToBoolean`, and to a lesser extent, `ToPrimitive`.

`ToString`

When any non-`string` value is coerced to a `string` representation, the conversion is handled by the `ToString` abstract operation in section 9.8 of the specification.

Built-in primitive values have natural stringification: `null` becomes `"null"`, `undefined` becomes `"undefined"` and `true` becomes `"true"`. `number`s are generally expressed in the natural way you'd expect, but as we discussed in Chapter 2, very small or very large `numbers` are represented in exponent form:

```
// multiplying `1.07` by `1000`, seven times over
var a = 1.07 * 1000 * 1000 * 1000 * 1000 * 1000 * 1000 * 1000;

// seven times three digits => 21 digits
a.toString(); // "1.07e21"
```

For regular objects, unless you specify your own, the default `toString()` (located in `Object.prototype.toString()`) will return the *internal* *`[[Class]]`* (see Chapter 3), like for instance `"[object Object]"`.

But as shown earlier, if an object has its own `toString()` method on it, and you use that object in a `string`-like way, its `toString()` will automatically be called, and the `string` result of that call will be used instead.

Note: The way an object is coerced to a `string` technically goes through the `ToPrimitive` abstract operation (ES5 spec, section 9.1), but those nuanced details are covered in more detail in the `ToNumber` section later in this chapter, so we will skip over them here.

Arrays have an overridden default `toString()` that stringifies as the (string) concatenation of all its values (each stringified themselves), with `","` in between each value:

```
var a = [1,2,3];

a.toString(); // "1,2,3"
```

Again, `toString()` can either be called explicitly, or it will automatically be called if a non-`string` is used in a `string` context.

JSON Stringification

Another task that seems awfully related to `ToString` is when you use the `JSON.stringify(..)` utility to serialize a value to a JSON-compatible `string` value.

It's important to note that this stringification is not exactly the same thing as coercion. But since it's related to the `ToString` rules above, we'll take a slight diversion to cover JSON stringification behaviors here.
For most simple values, JSON stringification behaves basically the same as `toString()` conversions, except that the serialization result is *always a `string`*:

```
JSON.stringify( 42 );    // "42"
JSON.stringify( "42" );  // ""42"" (a string with a quoted string value in it)
JSON.stringify( null );  // "null"
JSON.stringify( true );  // "true"
```

Any *JSON-safe* value can be stringified by `JSON.stringify(..)`. But what is *JSON-safe*? Any value that can be represented validly in a JSON representation.
It may be easier to consider values that are **not** JSON-safe. Some examples: `undefined`s, `function`s, (ES6+) `symbol`s, and `object`s with circular references (where property references in an object structure create a never-ending cycle through each other). These are all illegal values for a standard JSON structure, mostly because they aren't portable to other languages that consume JSON values.
The `JSON.stringify(..)` utility will automatically omit `undefined`, `function`, and `symbol` values when it comes across them. If such a value is found in an `array`, that value is replaced by `null` (so that the array position information isn't altered). If found as a property of an `object`, that property will simply be excluded.
Consider:

```
JSON.stringify( undefined );                                       // undefined
JSON.stringify( function(){} );                                    // undefined

JSON.stringify( [1,undefined,function(){},4] );   // "[1,null,null,4]"
JSON.stringify( { a:2, b:function(){} } );                // "{"a":2}"
```

But if you try to `JSON.stringify(..)` an `object` with circular reference(s) in it, an error will be thrown.
JSON stringification has the special behavior that if an `object` value has a `toJSON()` method defined, this method will be called first to get a value to use for serialization.
If you intend to JSON stringify an object that may contain illegal JSON value(s), or if you just have values in the `object` that aren't appropriate for the serialization, you should define a `toJSON()` method for it that returns a *JSON-safe* version of the `object`.
For example:

```
var o = { };

var a = {
        b: 42,
        c: o,
        d: function(){}
};
```

```
// create a circular reference inside `a`
o.e = a;

// would throw an error on the circular reference
// JSON.stringify( a );

// define a custom JSON value serialization
a.toJSON = function() {
        // only include the `b` property for serialization
        return { b: this.b };
};

JSON.stringify( a ); // "{"b":42}"
```

It's a very common misconception that `toJSON()` should return a JSON stringification representation. That's probably incorrect, unless you're wanting to actually stringify the `string` itself (usually not!). `toJSON()` should return the actual regular value (of whatever type) that's appropriate, and `JSON.stringify(..)` itself will handle the stringification.
In other words, `toJSON()` should be interpreted as "to a JSON-safe value suitable for stringification," not "to a JSON string" as many developers mistakenly assume.
Consider:

```
var a = {
        val: [1,2,3],

        // probably correct!
        toJSON: function(){
                return this.val.slice( 1 );
        }
};

var b = {
        val: [1,2,3],

        // probably incorrect!
        toJSON: function(){
                return "[" +
                        this.val.slice( 1 ).join() +
                "]";
        }
};

JSON.stringify( a ); // "[2,3]"

JSON.stringify( b ); // ""[2,3]""
```

In the second call, we stringified the returned `string` rather than the `array` itself, which was probably not what we wanted to do.

While we're talking about `JSON.stringify(..)`, let's discuss some lesser-known functionalities that can still be very useful.
An optional second argument can be passed to `JSON.stringify(..)` that is called *replacer*. This argument can either be an `array` or a `function`. It's used to customize the recursive serialization of an `object` by providing a filtering mechanism for which properties should and should not be included, in a similar way to how `toJSON()` can prepare a value for serialization.
If *replacer* is an `array`, it should be an `array` of `string`s, each of which will specify a property name that is allowed to be included in the serialization of the `object`. If a property exists that isn't in this list, it will be skipped.
If *replacer* is a `function`, it will be called once for the `object` itself, and then once for each property in the `object`, and each time is passed two arguments, *key* and *value*. To skip a *key* in the serialization, return `undefined`. Otherwise, return the *value* provided.

```
var a = {
        b: 42,
        c: "42",
        d: [1,2,3]
};

JSON.stringify( a, ["b","c"] ); // "{"b":42,"c":"42"}"

JSON.stringify( a, function(k,v){
        if (k !== "c") return v;
} );
// "{"b":42,"d":[1,2,3]}"
```

Note: In the `function` *replacer* case, the key argument `k` is `undefined` for the first call (where the `a` object itself is being passed in). The `if` statement **filters out** the property named `"c"`. Stringification is recursive, so the `[1,2,3]` array has each of its values (`1`, `2`, and `3`) passed as `v` to *replacer*, with indexes (`0`, `1`, and `2`) as `k`.
A third optional argument can also be passed to `JSON.stringify(..)`, called *space*, which is used as indentation for prettier human-friendly output. *space* can be a positive integer to indicate how many space characters should be used at each indentation level.
Or, *space* can be a `string`, in which case up to the first ten characters of its value will be used for each indentation level.

```
var a = {
        b: 42,
        c: "42",
        d: [1,2,3]
};

JSON.stringify( a, null, 3 );
// "{
//    "b": 42,
//    "c": "42",
//    "d": [
//       1,
//       2,
//       3
//    ]
// }"

JSON.stringify( a, null, "-----" );
// "{
// -----"b": 42,
// -----"c": "42",
// -----"d": [
// ----------1,
// ----------2,
// ----------3
// -----]
// }"
```

Remember, `JSON.stringify(..)` is not directly a form of coercion. We covered it here, however, for two reasons that relate its behavior to `ToString` coercion:

1. `string`, `number`, `boolean`, and `null` values all stringify for JSON basically the same as how they coerce to `string` values via the rules of the `ToString` abstract operation.
2. If you pass an `object` value to `JSON.stringify(..)`, and that `object` has a `toJSON()` method on it, `toJSON()` is automatically called to (sort of) "coerce" the value to be *JSON-safe* before stringification.

`ToNumber`

If any non-`number` value is used in a way that requires it to be a `number`, such as a mathematical operation, the ES5 spec defines the `ToNumber` abstract operation in section 9.3.

For example, `true` becomes `1` and `false` becomes `0`. `undefined` becomes `NaN`, but (curiously) `null` becomes `0`.

`ToNumber` for a `string` value essentially works for the most part like the rules/syntax for numeric literals (see Chapter 3). If it fails, the result is `NaN` (instead of a syntax error as with `number` literals). One example difference is that `0`-prefixed octal numbers are not handled as octals (just as normal base-10 decimals) in this operation, though such octals are valid as `number` literals (see Chapter 2).

Note: The differences between `number` literal grammar and `ToNumber` on a `string` value are subtle and highly nuanced, and thus will not be covered further here. Consult section 9.3.1 of the ES5 spec for more information.

Objects (and arrays) will first be converted to their primitive value equivalent, and the resulting value (if a primitive but not already a `number`) is coerced to a `number` according to the `ToNumber` rules just mentioned.

To convert to this primitive value equivalent, the `ToPrimitive` abstract operation (ES5 spec, section 9.1) will consult the value (using the internal `DefaultValue` operation -- ES5 spec, section 8.12.8) in question to see if it has a `valueOf()` method. If `valueOf()` is

available and it returns a primitive value, *that* value is used for the coercion. If not, but `toString()` is available, it will provide the value for the coercion.
If neither operation can provide a primitive value, a `TypeError` is thrown.
As of ES5, you can create such a noncoercible object -- one without `valueOf()` and `toString()` -- if it has a `null` value for its `[[Prototype]]`, typically created with `Object.create(null)`. See the *this & Object Prototypes* title of this series for more information on `[[Prototype]]`s.
Note: We cover how to coerce to `number`s later in this chapter in detail, but for this next code snippet, just assume the `Number(..)` function does so.
Consider:

```
var a = {
	valueOf: function(){
		return "42";
	}
};

var b = {
	toString: function(){
		return "42";
	}
};

var c = [4,2];
c.toString = function(){
	return this.join( "" );	// "42"
};

Number( a );			// 42
Number( b );			// 42
Number( c );			// 42
Number( "" );			// 0
Number( [] );			// 0
Number( [ "abc" ] );	// NaN
```

`ToBoolean`

Next, let's have a little chat about how `boolean`s behave in JS. There's **lots of confusion and misconception** floating out there around this topic, so pay close attention!
First and foremost, JS has actual keywords `true` and `false`, and they behave exactly as you'd expect of `boolean` values. It's a common misconception that the values `1` and `0` are identical to `true`/`false`. While that may be true in other languages, in JS the `number`s are `number`s and the `boolean`s are `boolean`s. You can coerce `1` to `true` (and vice versa) or `0` to `false` (and vice versa). But they're not the same.

Falsy Values

But that's not the end of the story. We need to discuss how values other than the two `booleans` behave whenever you coerce *to* their `boolean` equivalent.
All of JavaScript's values can be divided into two categories:

1. values that will become `false` if coerced to `boolean`
2. everything else (which will obviously become `true`)

I'm not just being facetious. The JS spec defines a specific, narrow list of values that will coerce to `false` when coerced to a `boolean` value.
How do we know what the list of values is? In the ES5 spec, section 9.2 defines a `ToBoolean` abstract operation, which says exactly what happens for all the possible values when you try to coerce them "to boolean."
From that table, we get the following as the so-called "falsy" values list:

- `undefined`
- `null`
- `false`
- `+0`, `-0`, and `NaN`
- `""`

That's it. If a value is on that list, it's a "falsy" value, and it will coerce to `false` if you force a `boolean` coercion on it.
By logical conclusion, if a value is *not* on that list, it must be on *another list*, which we call the "truthy" values list. But JS doesn't really define a "truthy" list per se. It gives some examples, such as saying explicitly that all objects are truthy, but mostly the spec just implies: **anything not explicitly on the falsy list is therefore truthy.**

Falsy Objects

Wait a minute, that section title even sounds contradictory. I literally *just said* the spec calls all objects truthy, right? There should be no such thing as a "falsy object."

What could that possibly even mean?

You might be tempted to think it means an object wrapper (see Chapter 3) around a falsy value (such as `""`, `0` or `false`). But don't fall into that *trap*.
Note: That's a subtle specification joke some of you may get.

Consider:

```
var a = new Boolean( false );
var b = new Number( 0 );
var c = new String( "" );
```

We know all three values here are objects (see Chapter 3) wrapped around obviously falsy values. But do these objects behave as `true` or as `false`? That's easy to answer:

```
var d = Boolean( a && b && c );

d; // true
```

So, all three behave as `true`, as that's the only way `d` could end up as `true`.
Tip: Notice the `Boolean( .. )` wrapped around the `a && b && c` expression -- you might wonder why that's there. We'll come back to that later in this chapter, so make a mental note of it. For a sneak-peek (trivia-wise), try for yourself what `d` will be if you just do `d = a && b && c` without the `Boolean( .. )` call!
So, if "falsy objects" are **not just objects wrapped around falsy values**, what the heck are they?

The tricky part is that they can show up in your JS program, but they're not actually part of JavaScript itself.

What!?

There are certain cases where browsers have created their own sort of *exotic* values behavior, namely this idea of "falsy objects," on top of regular JS semantics.

A "falsy object" is a value that looks and acts like a normal object (properties, etc.), but when you coerce it to a `boolean`, it coerces to a `false` value.
Why!?

The most well-known case is `document.all`: an array-like (object) provided to your JS program *by the DOM* (not the JS engine itself), which exposes elements in your page to your JS program. It *used* to behave like a normal object--it would act truthy. But not anymore.
`document.all` itself was never really "standard" and has long since been deprecated/abandoned.
"Can't they just remove it, then?" Sorry, nice try. Wish they could. But there's far too many legacy JS code bases out there that rely on using it.

So, why make it act falsy? Because coercions of `document.all` to `boolean` (like in `if` statements) were almost always used as a means of detecting old, nonstandard IE. IE has long since come up to standards compliance, and in many cases is pushing the web forward as much or more than any other browser. But all that old `if (document.all) { /* it's IE */ }` code is still out there, and much of it is probably never going away. All this legacy code is still assuming it's running in decade-old IE, which just leads to bad browsing experience for IE users.

So, we can't remove `document.all` completely, but IE doesn't want `if (document.all) { .. }` code to work anymore, so that users in modern IE get new, standards-compliant code logic.
"What should we do?" **"I've got it! Let's bastardize the JS type system and pretend that `document.all` is falsy!"
Ugh. That sucks. It's a crazy gotcha that most JS developers don't understand. But the alternative (doing nothing about the above no-win problems) sucks *just a little bit more*.

So... that's what we've got: crazy, nonstandard "falsy objects" added to JavaScript by the browsers. Yay!

Truthy Values

Back to the truthy list. What exactly are the truthy values? Remember: **a value is truthy if it's not on the falsy list.**

Consider:

```
var a = "false";
var b = "0";
var c = "''";

var d = Boolean( a && b && c );

d;
```

What value do you expect `d` to have here? It's gotta be either `true` or `false`.
It's `true`. Why? Because despite the contents of those `string` values looking like falsy values, the `string` values themselves are all truthy, because `""` is the only `string` value on the falsy list.
What about these?

```
var a = [];                              // empty array -- truthy or falsy?
var b = {};                              // empty object -- truthy or falsy?
var c = function(){};    // empty function -- truthy or falsy?

var d = Boolean( a && b && c );

d;
```

Yep, you guessed it, `d` is still `true` here. Why? Same reason as before. Despite what it may seem like, `[]`, `{}`, and `function(){}` are *not* on the falsy list, and thus are truthy values.
In other words, the truthy list is infinitely long. It's impossible to make such a list. You can only make a finite falsy list and consult *it*.

Take five minutes, write the falsy list on a post-it note for your computer monitor, or memorize it if you prefer. Either way, you'll easily be able to construct a virtual truthy list whenever you need it by simply asking if it's on the falsy list or not.

The importance of truthy and falsy is in understanding how a value will behave if you coerce it (either explicitly or implicitly) to a `boolean` value. Now that you have those two lists in mind, we can dive into coercion examples themselves.

Explicit Coercion

Explicit coercion refers to type conversions that are obvious and explicit. There's a wide range of type conversion usage that clearly falls under the *explicit* coercion category for most developers.

The goal here is to identify patterns in our code where we can make it clear and obvious that we're converting a value from one type to another, so as to not leave potholes for future developers to trip into. The more explicit we are, the more likely someone later will be able to read our code and understand without undue effort what our intent was.

It would be hard to find any salient disagreements with *explicit* coercion, as it most closely aligns with how the commonly accepted practice of type conversion works in statically typed languages. As such, we'll take for granted (for now) that *explicit* coercion can be agreed upon to not be evil or controversial. We'll revisit this later, though.

Explicitly: Strings <--> Numbers

We'll start with the simplest and perhaps most common coercion operation: coercing values between `string` and `number` representation.
To coerce between `string`s and `number`s, we use the built-in `String(..)` and `Number(..)` functions (which we referred to as "native constructors" in Chapter 3), but **very importantly**, we do not use the `new` keyword in front of them. As such, we're not creating object wrappers.
Instead, we're actually *explicitly coercing* between the two types:

```
var a = 42;
var b = String( a );

var c = "3.14";
var d = Number( c );

b; // "42"
d; // 3.14
```

`String(..)` coerces from any other value to a primitive `string` value, using the rules of the `ToString` operation discussed earlier. `Number(..)` coerces from any other value to a primitive `number` value, using the rules of the `ToNumber` operation discussed earlier.
I call this *explicit* coercion because in general, it's pretty obvious to most developers that the end result of these operations is the applicable type conversion.

In fact, this usage actually looks a lot like it does in some other statically typed languages.

For example, in C/C++, you can say either `(int)x` or `int(x)`, and both will convert the value in `x` to an integer. Both forms are valid, but many prefer the latter, which kinda looks like a function call. In JavaScript, when you say `Number(x)`, it looks awfully similar. Does it matter that it's *actually* a function call in JS? Not really.
Besides `String(..)` and `Number(..)`, there are other ways to "explicitly" convert these values between `string` and `number`:
```
var a = 42;
var b = a.toString();

var c = "3.14";
var d = +c;

b; // "42"
d; // 3.14
```

Calling `a.toString()` is ostensibly explicit (pretty clear that "toString" means "to a string"), but there's some hidden implicitness here. `toString()` cannot be called on a *primitive* value like `42`. So JS automatically "boxes" (see Chapter 3) `42` in an object wrapper, so that `toString()` can be called against the object. In other words, you might call it "explicitly implicit."
`+c` here is showing the *unary operator* form (operator with only one operand) of the `+` operator. Instead of performing mathematic addition (or string concatenation -- see below), the unary `+` explicitly coerces its operand (`c`) to a `number` value.
Is `+c` *explicit* coercion? Depends on your experience and perspective. If you know (which you do, now!) that unary `+` is explicitly intended for `number` coercion, then it's pretty explicit and obvious. However, if you've never seen it before, it can seem awfully confusing, implicit, with hidden side effects, etc.
Note: The generally accepted perspective in the open-source JS community is that unary `+` is an accepted form of *explicit* coercion.
Even if you really like the `+c` form, there are definitely places where it can look awfully confusing. Consider:
```
var c = "3.14";
var d = 5+ +c;

d; // 8.14
```

The unary `-` operator also coerces like `+` does, but it also flips the sign of the number. However, you cannot put two `--` next to each other to unflip the sign, as that's parsed as the decrement operator. Instead, you would need to do: `- -"3.14"` with a space in between, and that would result in coercion to `3.14`.
You can probably dream up all sorts of hideous combinations of binary operators (like `+` for addition) next to the unary form of an operator. Here's another crazy example:

```
1 + - + + + - + 1;       // 2
```

You should strongly consider avoiding unary `+` (or `-`) coercion when it's immediately adjacent to other operators. While the above works, it would almost universally be considered a bad idea. Even `d = +c` (or `d =+ c` for that matter!) can far too easily be confused for `d += c`, which is entirely different!
Note: Another extremely confusing place for unary `+` to be used adjacent to another operator would be the `++` increment operator and `--` decrement operator. For example: `a +++b`, `a + ++b`, and `a + + +b`. See "Expression Side-Effects" in Chapter 5 for more about `++`.
Remember, we're trying to be explicit and **reduce** confusion, not make it much worse!

`Date` To `number`

Another common usage of the unary `+` operator is to coerce a `Date` object into a `number`, because the result is the unix timestamp (milliseconds elapsed since 1 January 1970 00:00:00 UTC) representation of the date/time value:

```
var d = new Date( "Mon, 18 Aug 2014 08:53:06 CDT" );

+d; // 1408369986000
```

The most common usage of this idiom is to get the current *now* moment as a timestamp, such as:

```
var timestamp = +new Date();
```

Note: Some developers are aware of a peculiar syntactic "trick" in JavaScript, which is that the `()` set on a constructor call (a function called with `new`) is *optional* if there are no arguments to pass. So you may run across the `var timestamp = +new Date;` form. However, not all developers agree that omitting the `()` improves readability, as it's an uncommon syntax exception that only applies to the `new fn()` call form and not the regular `fn()` call form.
But coercion is not the only way to get the timestamp out of a `Date` object. A noncoercion approach is perhaps even preferable, as it's even more explicit:

```
var timestamp = new Date().getTime();
// var timestamp = (new Date()).getTime();
// var timestamp = (new Date).getTime();
```

But an *even more* preferable noncoercion option is to use the ES5 added `Date.now()` static function:

```
var timestamp = Date.now();
```

And if you want to polyfill `Date.now()` into older browsers, it's pretty simple:

```
if (!Date.now) {
	Date.now = function() {
		return +new Date();
	};
}
```

I'd recommend skipping the coercion forms related to dates. Use `Date.now()` for current *now* timestamps, and `new Date( .. ).getTime()` for getting a timestamp of a specific *non-now* date/time that you need to specify.

The Curious Case of the ~

One coercive JS operator that is often overlooked and usually very confused is the tilde `~` operator (aka "bitwise NOT"). Many of those who even understand what it does will often times still want to avoid it. But sticking to the spirit of our approach in this book and series, let's dig into it to find out if `~` has anything useful to give us.

In the "32-bit (Signed) Integers" section of Chapter 2, we covered how bitwise operators in JS are defined only for 32-bit operations, which means they force their operands to conform to 32-bit value representations. The rules for how this happens are controlled by the `ToInt32` abstract operation (ES5 spec, section 9.5).

`ToInt32` first does a `ToNumber` coercion, which means if the value is `"123"`, it's going to first become `123` before the `ToInt32` rules are applied.

While not *technically* coercion itself (since the type doesn't change!), using bitwise operators (like `|` or `~`) with certain special `number` values produces a coercive effect that results in a different `number` value.

For example, let's first consider the `|` "bitwise OR" operator used in the otherwise no-op idiom `0 | x`, which (as Chapter 2 showed) essentially only does the `ToInt32` conversion:

```
0 | -0;			// 0
0 | NaN;		// 0
0 | Infinity;	// 0
0 | -Infinity;	// 0
```

These special numbers aren't 32-bit representable (since they come from the 64-bit IEEE 754 standard -- see Chapter 2), so `ToInt32` just specifies `0` as the result from these values.

It's debatable if `0 | __` is an *explicit* form of this coercive `ToInt32` operation or if it's more *implicit*. From the spec perspective, it's unquestionably *explicit*, but if you don't understand bitwise operations at this level, it can seem a bit more *implicitly* magical. Nevertheless, consistent with other assertions in this chapter, we will call it *explicit*.

So, let's turn our attention back to `~`. The `~` operator first "coerces" to a 32-bit `number` value, and then performs a bitwise negation (flipping each bit's parity).

Note: This is very similar to how `!` not only coerces its value to `boolean` but also flips its parity (see discussion of the "unary `!`" later).

But... what!? Why do we care about bits being flipped? That's some pretty specialized, nuanced stuff. It's pretty rare for JS developers to need to reason about individual bits.

Another way of thinking about the definition of ~ comes from old-school computer science/discrete Mathematics: ~ performs two's-complement. Great, thanks, that's totally clearer!
Let's try again: `~x` is roughly the same as `-(x+1)`. That's weird, but slightly easier to reason about. So:

```
~42;    // -(42+1) ==> -43
```

You're probably still wondering what the heck all this ~ stuff is about, or why it really matters for a coercion discussion. Let's quickly get to the point.
Consider `-(x+1)`. What's the only value that you can perform that operation on that will produce a `0` (or `-0` technically!) result? `-1`. In other words, ~ used with a range of `number` values will produce a falsy (easily coercible to `false`) `0` value for the `-1` input value, and any other truthy `number` otherwise.
Why is that relevant?

`-1` is commonly called a "sentinel value," which basically means a value that's given an arbitrary semantic meaning within the greater set of values of its same type (`number`s). The C-language uses `-1` sentinel values for many functions that return `>= 0` values for "success" and `-1` for "failure."
JavaScript adopted this precedent when defining the `string` operation `indexOf(..)`, which searches for a substring and if found returns its zero-based index position, or `-1` if not found.
It's pretty common to try to use `indexOf(..)` not just as an operation to get the position, but as a `boolean` check of presence/absence of a substring in another `string`. Here's how developers usually perform such checks:

```
var a = "Hello World";

if (a.indexOf( "lo" ) >= 0) {     // true
        // found it!
}
if (a.indexOf( "lo" ) != -1) {    // true
        // found it
}

if (a.indexOf( "ol" ) < 0) {      // true
        // not found!
}
if (a.indexOf( "ol" ) == -1) {    // true
        // not found!
}
```

I find it kind of gross to look at `>= 0` or `== -1`. It's basically a "leaky abstraction," in that it's leaking underlying implementation behavior -- the usage of sentinel `-1` for "failure" -- into my code. I would prefer to hide such a detail.
And now, finally, we see why ~ could help us! Using ~ with `indexOf()` "coerces" (actually just transforms) the value **to be appropriately `boolean`-coercible**:

```
var a = "Hello World";

~a.indexOf( "lo" );                      // -4   <-- truthy!

if (~a.indexOf( "lo" )) {         // true
        // found it!
}

~a.indexOf( "ol" );                      // 0    <-- falsy!
!~a.indexOf( "ol" );             // true

if (!~a.indexOf( "ol" )) {        // true
        // not found!
}
```

~ takes the return value of `indexOf(..)` and transforms it: for the "failure" `-1` we get the falsy `0`, and every other value is truthy.
Note: The `-(x+1)` pseudo-algorithm for ~ would imply that `~-1` is `-0`, but actually it produces `0` because the underlying operation is actually bitwise, not mathematic.
Technically, `if (~a.indexOf(..))` is still relying on *implicit* coercion of its resultant `0` to `false` or nonzero to `true`. But overall, ~ still feels to me more like an *explicit* coercion mechanism, as long as you know what it's intended to do in this idiom.
I find this to be cleaner code than the previous `>= 0` / `== -1` clutter.

Truncating Bits

There's one more place ~ may show up in code you run across: some developers use the double tilde ~~ to truncate the decimal part of a `number` (i.e., "coerce" it to a whole number "integer"). It's commonly (though mistakingly) said this is the same result as calling `Math.floor(..)`.
How ~~ works is that the first ~ applies the `ToInt32` "coercion" and does the bitwise flip, and then the second ~ does another bitwise flip, flipping all the bits back to the original state. The end result is just the `ToInt32` "coercion" (aka truncation).
Note: The bitwise double-flip of ~~ is very similar to the parity double-negate `!!` behavior, explained in the "Explicitly: * --> Boolean" section later.
However, ~~ needs some caution/clarification. First, it only works reliably on 32-bit values. But more importantly, it doesn't work the same on negative numbers as `Math.floor(..)` does!

```
Math.floor( -49.6 );     // -50
~~-49.6;                         // -49
```

Setting the `Math.floor(..)` difference aside, `~~x` can truncate to a (32-bit) integer. But so does `x | 0`, and seemingly with (slightly) *less effort*.
So, why might you choose `~~x` over `x | 0`, then? Operator precedence (see Chapter 5):

```
~~1E20 / 10;             // 166199296
```

```
1E20 | 0 / 10;           // 1661992960
(1E20 | 0) / 10; // 166199296
```

Just as with all other advice here, use ~ and ~~ as explicit mechanisms for "coercion" and value transformation only if everyone who reads/writes such code is properly aware of how these operators work!

Explicitly: Parsing Numeric Strings

A similar outcome to coercing a `string` to a `number` can be achieved by parsing a `number` out of a `string`'s character contents. There are, however, distinct differences between this parsing and the type conversion we examined above.
Consider:

```
var a = "42";
var b = "42px";

Number( a );     // 42
parseInt( a );   // 42

Number( b );     // NaN
parseInt( b );   // 42
```

Parsing a numeric value out of a string is *tolerant* of non-numeric characters -- it just stops parsing left-to-right when encountered -- whereas coercion is *not tolerant* and fails resulting in the `NaN` value.
Parsing should not be seen as a substitute for coercion. These two tasks, while similar, have different purposes. Parse a `string` as a `number` when you don't know/care what other non-numeric characters there may be on the right-hand side. Coerce a `string` (to a `number`) when the only acceptable values are numeric and something like `"42px"` should be rejected as a `number`.
Tip: `parseInt(..)` has a twin, `parseFloat(..)`, which (as it sounds) pulls out a floating-point number from a string.
Don't forget that `parseInt(..)` operates on `string` values. It makes absolutely no sense to pass a `number` value to `parseInt(..)`. Nor would it make sense to pass any other type of value, like `true`, `function(){..}` or `[1,2,3]`.
If you pass a non-`string`, the value you pass will automatically be coerced to a `string` first (see "`ToString`" earlier), which would clearly be a kind of hidden *implicit* coercion. It's a really bad idea to rely upon such a behavior in your program, so never use `parseInt(..)` with a non-`string` value.
Prior to ES5, another gotcha existed with `parseInt(..)`, which was the source of many JS programs' bugs. If you didn't pass a second argument to indicate which numeric base

(aka radix) to use for interpreting the numeric `string` contents, `parseInt(..)` would look at the beginning character(s) to make a guess.
If the first two characters were `"0x"` or `"0X"`, the guess (by convention) was that you wanted to interpret the `string` as a hexadecimal (base-16) `number`. Otherwise, if the first character was `"0"`, the guess (again, by convention) was that you wanted to interpret the `string` as an octal (base-8) `number`.
Hexadecimal `string`s (with the leading `0x` or `0X`) aren't terribly easy to get mixed up. But the octal number guessing proved devilishly common. For example:

```
var hour = parseInt( selectedHour.value );
var minute = parseInt( selectedMinute.value );

console.log( "The time you selected was: " + hour + ":" + minute);
```

Seems harmless, right? Try selecting `08` for the hour and `09` for the minute. You'll get `0:0`. Why? because neither `8` nor `9` are valid characters in octal base-8.
The pre-ES5 fix was simple, but so easy to forget: **always pass `10` as the second argument**. This was totally safe:

```
var hour = parseInt( selectedHour.value, 10 );
var minute = parseInt( selectedMiniute.value, 10 );
```

As of ES5, `parseInt(..)` no longer guesses octal. Unless you say otherwise, it assumes base-10 (or base-16 for `"0x"` prefixes). That's much nicer. Just be careful if your code has to run in pre-ES5 environments, in which case you still need to pass `10` for the radix.

Parsing Non-Strings

One somewhat infamous example of `parseInt(..)`'s behavior is highlighted in a sarcastic joke post a few years ago, poking fun at this JS behavior:

```
parseInt( 1/0, 19 ); // 18
```

The assumptive (but totally invalid) assertion was, "If I pass in Infinity, and parse an integer out of that, I should get Infinity back, not 18." Surely, JS must be crazy for this outcome, right?

Though this example is obviously contrived and unreal, let's indulge the madness for a moment and examine whether JS really is that crazy.

First off, the most obvious sin committed here is to pass a non-`string` to `parseInt(..)`. That's a no-no. Do it and you're asking for trouble. But even if you do, JS politely coerces what you pass in into a `string` that it can try to parse.
Some would argue that this is unreasonable behavior, and that `parseInt(..)` should refuse to operate on a non-`string` value. Should it perhaps throw an error? That would be very Java-like, frankly. I shudder at thinking JS should start throwing errors all over the place so that `try..catch` is needed around almost every line.

Should it return `NaN`? Maybe. But... what about:

```
parseInt( new String( "42") );
```

Should that fail, too? It's a non-`string` value. If you want that `String` object wrapper to be unboxed to `"42"`, then is it really so unusual for `42` to first become `"42"` so that `42` can be parsed back out?
I would argue that this half-*explicit*, half-*implicit* coercion that can occur can often be a very helpful thing. For example:

```
var a = {
        num: 21,
        toString: function() { return String( this.num * 2 ); }
};

parseInt( a ); // 42
```

The fact that `parseInt(..)` forcibly coerces its value to a `string` to perform the parse on is quite sensible. If you pass in garbage, and you get garbage back out, don't blame the trash can -- it just did its job faithfully.
So, if you pass in a value like `Infinity` (the result of `1 / 0` obviously), what sort of `string` representation would make the most sense for its coercion? Only two reasonable choices come to mind: `"Infinity"` and `"∞"`. JS chose `"Infinity"`. I'm glad it did.
I think it's a good thing that **all values** in JS have some sort of default `string` representation, so that they aren't mysterious black boxes that we can't debug and reason about.
Now, what about base-19? Obviously, completely bogus and contrived. No real JS programs use base-19. It's absurd. But again, let's indulge the ridiculousness. In base-19, the valid numeric characters are `0` - `9` and `a` - `i` (case insensitive).
So, back to our `parseInt( 1/0, 19 )` example. It's essentially `parseInt( "Infinity", 19 )`. How does it parse? The first character is `"I"`, which is value `18` in the silly base-19. The second character `"n"` is not in the valid set of numeric characters, and as such the parsing simply politely stops, just like when it ran across `"p"` in `"42px"`.
The result? `18`. Exactly like it sensibly should be. The behaviors involved to get us there, and not to an error or to `Infinity` itself, are **very important** to JS, and should not be so easily discarded.
Other examples of this behavior with `parseInt(..)` that may be surprising but are quite sensible include:

```
parseInt( 0.000008 );           // 0   ("0" from "0.000008")
parseInt( 0.0000008 );          // 8   ("8" from "8e-7")
parseInt( false, 16 );          // 250 ("fa" from "false")
parseInt( parseInt, 16 );       // 15  ("f" from "function..")

parseInt( "0x10" );                     // 16
parseInt( "103", 2 );           // 2
```

`parseInt(..)` is actually pretty predictable and consistent in its behavior. If you use it correctly, you'll get sensible results. If you use it incorrectly, the crazy results you get are not the fault of JavaScript.

Explicitly: * --> Boolean

Now, let's examine coercing from any non-`boolean` value to a `boolean`.
Just like with `String(..)` and `Number(..)` above, `Boolean(..)` (without the `new`, of course!) is an explicit way of forcing the `ToBoolean` coercion:

```
var a = "0";
var b = [];
var c = {};

var d = "";
var e = 0;
var f = null;
var g;

Boolean( a ); // true
Boolean( b ); // true
Boolean( c ); // true

Boolean( d ); // false
Boolean( e ); // false
Boolean( f ); // false
Boolean( g ); // false
```

While `Boolean(..)` is clearly explicit, it's not at all common or idiomatic.
Just like the unary `+` operator coerces a value to a `number` (see above), the unary `!` negate operator explicitly coerces a value to a `boolean`. The *problem* is that it also flips the value from truthy to falsy or vice versa. So, the most common way JS developers explicitly coerce to `boolean` is to use the `!!` double-negate operator, because the second `!` will flip the parity back to the original:

```
var a = "0";
var b = [];
var c = {};

var d = "";
var e = 0;
var f = null;
var g;

!!a;    // true
!!b;    // true
!!c;    // true

!!d;    // false
!!e;    // false
!!f;    // false
!!g;    // false
```

Any of these `ToBoolean` coercions would happen *implicitly* without the `Boolean(..)` or `!!`, if used in a `boolean` context such as an `if (..) ..` statement. But the goal here is to explicitly force the value to a `boolean` to make it clearer that the `ToBoolean` coercion is intended.
Another example use-case for explicit `ToBoolean` coercion is if you want to force a `true`/`false` value coercion in the JSON serialization of a data structure:

```
var a = [
	1,
	function(){ /*..*/ },
	2,
	function(){ /*..*/ }
];

JSON.stringify( a ); // "[1,null,2,null]"

JSON.stringify( a, function(key,val){
	if (typeof val == "function") {
		// force `ToBoolean` coercion of the function
		return !!val;
	}
	else {
		return val;
	}
} );
// "[1,true,2,true]"
```

If you come to JavaScript from Java, you may recognize this idiom:

```
var a = 42;

var b = a ? true : false;
```

The `? :` ternary operator will test `a` for truthiness, and based on that test will either assign `true` or `false` to `b`, accordingly.
On its surface, this idiom looks like a form of *explicit* `ToBoolean`-type coercion, since it's obvious that only either `true` or `false` come out of the operation.
However, there's a hidden *implicit* coercion, in that the `a` expression has to first be coerced to `boolean` to perform the truthiness test. I'd call this idiom "explicitly implicit."
Furthermore, I'd suggest **you should avoid this idiom completely** in JavaScript. It offers no real benefit, and worse, masquerades as something it's not.
`Boolean(a)` and `!!a` are far better as *explicit* coercion options.

Implicit Coercion

Implicit coercion refers to type conversions that are hidden, with non-obvious side-effects that implicitly occur from other actions. In other words, *implicit coercions* are any type conversions that aren't obvious (to you).

While it's clear what the goal of *explicit* coercion is (making code explicit and more understandable), it might be *too* obvious that *implicit* coercion has the opposite goal: making code harder to understand.

Taken at face value, I believe that's where much of the ire towards coercion comes from. The majority of complaints about "JavaScript coercion" are actually aimed (whether they realize it or not) at *implicit* coercion.

Note: Douglas Crockford, author of *"JavaScript: The Good Parts"*, has claimed in many conference talks and writings that JavaScript coercion should be avoided. But what he seems to mean is that *implicit* coercion is bad (in his opinion). However, if you read his own code, you'll find plenty of examples of coercion, both *implicit* and *explicit*! In truth, his angst seems to primarily be directed at the `==` operation, but as you'll see in this chapter, that's only part of the coercion mechanism.
So, **is implicit coercion** evil? Is it dangerous? Is it a flaw in JavaScript's design? Should we avoid it at all costs?

I bet most of you readers are inclined to enthusiastically cheer, "Yes!"

Not so fast. Hear me out.

Let's take a different perspective on what *implicit* coercion is, and can be, than just that it's "the opposite of the good explicit kind of coercion." That's far too narrow and misses an important nuance.

Let's define the goal of *implicit* coercion as: to reduce verbosity, boilerplate, and/or unnecessary implementation detail that clutters up our code with noise that distracts from the more important intent.

Simplifying Implicitly

Before we even get to JavaScript, let me suggest something pseudo-code'ish from some theoretical strongly typed language to illustrate:

```
SomeType x = SomeType( AnotherType( y ) )
```

In this example, I have some arbitrary type of value in `y` that I want to convert to the `SomeType` type. The problem is, this language can't go directly from whatever `y` currently is to `SomeType`. It needs an intermediate step, where it first converts to `AnotherType`, and then from `AnotherType` to `SomeType`.
Now, what if that language (or definition you could create yourself with the language) *did* just let you say:

```
SomeType x = SomeType( y )
```

Wouldn't you generally agree that we simplified the type conversion here to reduce the unnecessary "noise" of the intermediate conversion step? I mean, is it *really* all that important, right here at this point in the code, to see and deal with the fact that `y` goes to `AnotherType` first before then going to `SomeType`?
Some would argue, at least in some circumstances, yes. But I think an equal argument can be made of many other circumstances that here, the simplification **actually aids in the readability of the code** by abstracting or hiding away such details, either in the language itself or in our own abstractions.

Undoubtedly, behind the scenes, somewhere, the intermediate conversion step is still happening. But if that detail is hidden from view here, we can just reason about getting `y` to type `SomeType` as a generic operation and hide the messy details.
While not a perfect analogy, what I'm going to argue throughout the rest of this chapter is that JS *implicit* coercion can be thought of as providing a similar aid to your code.

But, **and this is very important**, that is not an unbounded, absolute statement. There are definitely plenty of *evils* lurking around *implicit* coercion, that will harm your code much more than any potential readability improvements. Clearly, we have to learn how to avoid such constructs so we don't poison our code with all manner of bugs.

Many developers believe that if a mechanism can do some useful thing **A** but can also be abused or misused to do some awful thing **Z**, then we should throw out that mechanism altogether, just to be safe.

My encouragement to you is: don't settle for that. Don't "throw the baby out with the bathwater." Don't assume *implicit* coercion is all bad because all you think you've ever seen is its "bad parts." I think there are "good parts" here, and I want to help and inspire more of you to find and embrace them!

Implicitly: Strings <--> Numbers

Earlier in this chapter, we explored *explicitly* coercing between `string` and `number` values. Now, let's explore the same task but with *implicit* coercion approaches. But before we do, we have to examine some nuances of operations that will *implicitly* force coercion.
The `+` operator is overloaded to serve the purposes of both `number` addition and `string` concatenation. So how does JS know which type of operation you want to use? Consider:

```
var a = "42";
var b = "0";

var c = 42;
var d = 0;

a + b; // "420"
c + d; // 42
```

What's different that causes `"420"` vs `42`? It's a common misconception that the difference is whether one or both of the operands is a `string`, as that means `+` will assume `string` concatenation. While that's partially true, it's more complicated than that. Consider:

```
var a = [1,2];
var b = [3,4];

a + b; // "1,23,4"
```

Neither of these operands is a `string`, but clearly they were both coerced to `string`s and then the `string` concatenation kicked in. So what's really going on?
(**Warning:** deeply nitty gritty spec-speak coming, so skip the next two paragraphs if that intimidates you!)

According to ES5 spec section 11.6.1, the `+` algorithm (when an `object` value is an operand) will concatenate if either operand is either already a `string`, or if the following steps produce a `string` representation. So, when `+` receives an `object` (including `array`) for either operand, it first calls the `ToPrimitive` abstract operation (section 9.1) on the value, which then calls the `[[DefaultValue]]` algorithm (section 8.12.8) with a context hint of `number`.
If you're paying close attention, you'll notice that this operation is now identical to how the `ToNumber` abstract operation handles `object`s (see the "`ToNumber`"" section earlier).
The `valueOf()` operation on the `array` will fail to produce a simple primitive, so it then falls to a `toString()` representation. The two `array`s thus become `"1,2"` and `"3,4"`, respectively. Now, `+` concatenates the two `string`s as you'd normally expect: `"1,23,4"`.

Let's set aside those messy details and go back to an earlier, simplified explanation: if either operand to `+` is a `string` (or becomes one with the above steps!), the operation will be `string` concatenation. Otherwise, it's always numeric addition.
Note: A commonly cited coercion gotcha is `[] + {}` vs. `{} + []`, as those two expressions result, respectively, in `"[object Object]"` and `0`. There's more to it, though, and we cover those details in "Blocks" in Chapter 5.
What's that mean for *implicit* coercion?

You can coerce a `number` to a `string` simply by "adding" the `number` and the `""` empty `string`:

```
var a = 42;
var b = a + "";

b; // "42"
```

Tip: Numeric addition with the `+` operator is commutative, which means `2 + 3` is the same as `3 + 2`. String concatenation with `+` is obviously not generally commutative, **but** with the specific case of `""`, it's effectively commutative, as `a + ""` and `"" + a` will produce the same result.
It's extremely common/idiomatic to (*implicitly*) coerce `number` to `string` with a `+ ""` operation. In fact, interestingly, even some of the most vocal critics of *implicit* coercion still use that approach in their own code, instead of one of its *explicit* alternatives.
I think this is a great example of a useful form in *implicit* coercion, despite how frequently the mechanism gets criticized!

Comparing this *implicit* coercion of `a + ""` to our earlier example of `String(a)` *explicit* coercion, there's one additional quirk to be aware of. Because of how the `ToPrimitive` abstract operation works, `a + ""` invokes `valueOf()` on the `a` value, whose return value is then finally converted to a `string` via the internal `ToString` abstract operation. But `String(a)` just invokes `toString()` directly.
Both approaches ultimately result in a `string`, but if you're using an `object` instead of a regular primitive `number` value, you may not necessarily get the *same* `string` value!
Consider:

```
var a = {
        valueOf: function() { return 42; },
        toString: function() { return 4; }
};

a + "";                  // "42"

String( a );    // "4"
```

Generally, this sort of gotcha won't bite you unless you're really trying to create confusing data structures and operations, but you should be careful if you're defining both your own `valueOf()` and `toString()` methods for some `object`, as how you coerce the value could affect the outcome.
What about the other direction? How can we *implicitly coerce* from `string` to `number`?

```
var a = "3.14";
var b = a - 0;

b; // 3.14
```

The - operator is defined only for numeric subtraction, so `a - 0` forces `a`'s value to be coerced to a `number`. While far less common, `a * 1` or `a / 1` would accomplish the same result, as those operators are also only defined for numeric operations.
What about `object` values with the - operator? Similar story as for `+` above:

```
var a = [3];
var b = [1];

a - b; // 2
```

Both `array` values have to become `number`s, but they end up first being coerced to `strings` (using the expected `toString()` serialization), and then are coerced to `number`s, for the - subtraction to perform on.
So, is *implicit* coercion of `string` and `number` values the ugly evil you've always heard horror stories about? I don't personally think so.
Compare `b = String(a)` (*explicit*) to `b = a + ""` (*implicit*). I think cases can be made for both approaches being useful in your code. Certainly `b = a + ""` is quite a bit more common in JS programs, proving its own utility regardless of *feelings* about the merits or hazards of *implicit* coercion in general.

Implicitly: Booleans --> Numbers

I think a case where *implicit* coercion can really shine is in simplifying certain types of complicated `boolean` logic into simple numeric addition. Of course, this is not a general-purpose technique, but a specific solution for specific cases.
Consider:

```
function onlyOne(a,b,c) {
        return !!((a && !b && !c) ||
                (!a && b && !c) || (!a && !b && c));
}

var a = true;
var b = false;

onlyOne( a, b, b );      // true
onlyOne( b, a, b );      // true

onlyOne( a, b, a );      // false
```

This `onlyOne(..)` utility should only return `true` if exactly one of the arguments is `true` / truthy. It's using *implicit* coercion on the truthy checks and *explicit* coercion on the others, including the final return value.
But what if we needed that utility to be able to handle four, five, or twenty flags in the same way? It's pretty difficult to imagine implementing code that would handle all those permutations of comparisons.

But here's where coercing the `boolean` values to `number`s (`0` or `1`, obviously) can greatly help:

```
function onlyOne() {
        var sum = 0;
        for (var i=0; i < arguments.length; i++) {
                // skip falsy values. same as treating
                // them as 0's, but avoids NaN's.
                if (arguments[i]) {
                        sum += arguments[i];
                }
        }
        return sum == 1;
}

var a = true;
var b = false;

onlyOne( b, a );         // true
onlyOne( b, a, b, b, b );        // true

onlyOne( b, b );         // false
onlyOne( b, a, b, b, b, a );     // false
```

Note: Of course, instead of the `for` loop in `onlyOne(..)`, you could more tersely use the ES5 `reduce(..)` utility, but I didn't want to obscure the concepts.
What we're doing here is relying on the `1` for `true`/truthy coercions, and numerically adding them all up. `sum += arguments[i]` uses *implicit* coercion to make that happen. If one and only one value in the `arguments` list is `true`, then the numeric sum will be `1`, otherwise the sum will not be `1` and thus the desired condition is not met.
We could of course do this with *explicit* coercion instead:

```
function onlyOne() {
        var sum = 0;
        for (var i=0; i < arguments.length; i++) {
                sum += Number( !!arguments[i] );
        }
        return sum === 1;
}
```

We first use `!!arguments[i]` to force the coercion of the value to `true` or `false`. That's so you could pass non-`boolean` values in, like `onlyOne( "42", 0 )`, and it would still work as expected (otherwise you'd end up with `string` concatenation and the logic would be incorrect).
Once we're sure it's a `boolean`, we do another *explicit* coercion with `Number(..)` to make sure the value is `0` or `1`.
Is the *explicit* coercion form of this utility "better"? It does avoid the `NaN` trap as explained in the code comments. But, ultimately, it depends on your needs. I personally think the former version, relying on *implicit* coercion is more elegant (if you won't be passing `undefined` or `NaN`), and the *explicit* version is needlessly more verbose.

But as with almost everything we're discussing here, it's a judgment call.

Note: Regardless of *implicit* or *explicit* approaches, you could easily make `onlyTwo(..)` or `onlyFive(..)` variations by simply changing the final comparison from `1`, to `2` or `5`, respectively. That's drastically easier than adding a bunch of `&&` and `||` expressions. So, generally, coercion is very helpful in this case.

Implicitly: * --> Boolean

Now, let's turn our attention to *implicit* coercion to `boolean` values, as it's by far the most common and also by far the most potentially troublesome.
Remember, *implicit* coercion is what kicks in when you use a value in such a way that it forces the value to be converted. For numeric and `string` operations, it's fairly easy to see how the coercions can occur.
But, what sort of expression operations require/force (*implicitly*) a `boolean` coercion?

1. The test expression in an `if (..)` statement.
2. The test expression (second clause) in a `for ( .. ; .. ; .. )` header.
3. The test expression in `while (..)` and `do..while(..)` loops.
4. The test expression (first clause) in `? :` ternary expressions.
5. The left-hand operand (which serves as a test expression -- see below!) to the `||` ("logical or") and `&&` ("logical and") operators.

Any value used in these contexts that is not already a `boolean` will be *implicitly* coerced to a `boolean` using the rules of the `ToBoolean` abstract operation covered earlier in this chapter.
Let's look at some examples:

```
var a = 42;
var b = "abc";
var c;
var d = null;

if (a) {
	console.log( "yep" );		// yep
}

while (c) {
	console.log( "nope, never runs" );
}

c = d ? a : b;
c;					// "abc"

if ((a && d) || c) {
	console.log( "yep" );		// yep
}
```

In all these contexts, the non-`boolean` values are *implicitly coerced* to their `boolean` equivalents to make the test decisions.

Operators `||` and `&&`

It's quite likely that you have seen the `||` ("logical or") and `&&` ("logical and") operators in most or all other languages you've used. So it'd be natural to assume that they work basically the same in JavaScript as in other similar languages.
There's some very little known, but very important, nuance here.

In fact, I would argue these operators shouldn't even be called "logical ___ operators", as that name is incomplete in describing what they do. If I were to give them a more accurate (if more clumsy) name, I'd call them "selector operators," or more completely, "operand selector operators."

Why? Because they don't actually result in a *logic* value (aka `boolean`) in JavaScript, as they do in some other languages.
So what *do* they result in? They result in the value of one (and only one) of their two operands. In other words, **they select one of the two operand's values**.

Quoting the ES5 spec from section 11.11:

The value produced by a && or || operator is not necessarily of type Boolean. The value produced will always be the value of one of the two operand expressions.

Let's illustrate:

```
var a = 42;
var b = "abc";
var c = null;

a || b;         // 42
a && b;         // "abc"

c || b;         // "abc"
c && b;         // null
```

Wait, what!? Think about that. In languages like C and PHP, those expressions result in `true` or `false`, but in JS (and Python and Ruby, for that matter!), the result comes from the values themselves.
Both `||` and `&&` operators perform a `boolean` test on the **first operand** (`a` or `c`). If the operand is not already `boolean` (as it's not, here), a normal `ToBoolean` coercion occurs, so that the test can be performed.

For the `||` operator, if the test is `true`, the `||` expression results in the value of the *first operand* (`a` or `c`). If the test is `false`, the `||` expression results in the value of the *second operand* (`b`).
Inversely, for the `&&` operator, if the test is `true`, the `&&` expression results in the value of the *second operand* (`b`). If the test is `false`, the `&&` expression results in the value of the *first operand* (`a` or `c`).
The result of a `||` or `&&` expression is always the underlying value of one of the operands, **not** the (possibly coerced) result of the test. In `c && b`, `c` is `null`, and thus falsy. But the `&&` expression itself results in `null` (the value in `c`), not in the coerced `false` used in the test.
Do you see how these operators act as "operand selectors", now?

Another way of thinking about these operators:

```
a || b;
// roughly equivalent to:
a ? a : b;

a && b;
// roughly equivalent to:
a ? b : a;
```

Note: I call `a || b` "roughly equivalent" to `a ? a : b` because the outcome is identical, but there's a nuanced difference. In `a ? a : b`, if `a` was a more complex expression (like for instance one that might have side effects like calling a `function`, etc.), then the `a` expression would possibly be evaluated twice (if the first evaluation was truthy). By contrast, for `a || b`, the `a` expression is evaluated only once, and that value is used both for the coercive test as well as the result value (if appropriate). The same nuance applies to the `a && b` and `a ? b : a` expressions.
An extremely common and helpful usage of this behavior, which there's a good chance you may have used before and not fully understood, is:

```
function foo(a,b) {
        a = a || "hello";
        b = b || "world";

        console.log( a + " " + b );
}

foo();                                   // "hello world"
foo( "yeah", "yeah!" );  // "yeah yeah!"
```

The `a = a || "hello"` idiom (sometimes said to be JavaScript's version of the C# "null coalescing operator") acts to test `a` and if it has no value (or only an undesired falsy value), provides a backup default value (`"hello"`).
Be careful, though!

```
foo( "That's it!", "" ); // "That's it! world" <-- Oops!
```

See the problem? `""` as the second argument is a falsy value (see `ToBoolean` earlier in this chapter), so the `b = b || "world"` test fails, and the `"world"` default value is substituted, even though the intent probably was to have the explicitly passed `""` be the value assigned to `b`.
This `||` idiom is extremely common, and quite helpful, but you have to use it only in cases where *all falsy values* should be skipped. Otherwise, you'll need to be more explicit in your test, and probably use a `? :` ternary instead.
This *default value assignment* idiom is so common (and useful!) that even those who publicly and vehemently decry JavaScript coercion often use it in their own code!

What about `&&`?
There's another idiom that is quite a bit less commonly authored manually, but which is used by JS minifiers frequently. The `&&` operator "selects" the second operand if and only if the first operand tests as truthy, and this usage is sometimes called the "guard operator" (also see "Short Circuited" in Chapter 5) -- the first expression test "guards" the second expression:

```
function foo() {
	console.log( a );
}

var a = 42;

a && foo(); // 42
```

`foo()` gets called only because `a` tests as truthy. If that test failed, this `a && foo()` expression statement would just silently stop -- this is known as "short circuiting" -- and never call `foo()`.
Again, it's not nearly as common for people to author such things. Usually, they'd do `if (a) { foo(); }` instead. But JS minifiers choose `a && foo()` because it's much shorter. So, now, if you ever have to decipher such code, you'll know what it's doing and why.
OK, so `||` and `&&` have some neat tricks up their sleeve, as long as you're willing to allow the *implicit* coercion into the mix.
Note: Both the `a = b || "something"` and `a && b()` idioms rely on short circuiting behavior, which we cover in more detail in Chapter 5.
The fact that these operators don't actually result in `true` and `false` is possibly messing with your head a little bit by now. You're probably wondering how all your `if` statements and `for` loops have been working, if they've included compound logical expressions like `a && (b || c)`.
Don't worry! The sky is not falling. Your code is (probably) just fine. It's just that you probably never realized before that there was an *implicit* coercion to `boolean` going on **after** the compound expression was evaluated.

Consider:

```
var a = 42;
var b = null;
var c = "foo";

if (a && (b || c)) {
        console.log( "yep" );
}
```

This code still works the way you always thought it did, except for one subtle extra detail. The `a && (b || c)` expression *actually* results in `"foo"`, not `true`. So, the `if` statement *then* forces the `"foo"` value to coerce to a `boolean`, which of course will be `true`.
See? No reason to panic. Your code is probably still safe. But now you know more about how it does what it does.

And now you also realize that such code is using *implicit* coercion. If you're in the "avoid (implicit) coercion camp" still, you're going to need to go back and make all of those tests *explicit*:

```
if (!!a && (!!b || !!c)) {
        console.log( "yep" );
}
```

Good luck with that! ... Sorry, just teasing.

Symbol Coercion

Up to this point, there's been almost no observable outcome difference between *explicit* and *implicit* coercion -- only the readability of code has been at stake.

But ES6 Symbols introduce a gotcha into the coercion system that we need to discuss briefly. For reasons that go well beyond the scope of what we'll discuss in this book, *explicit* coercion of a `symbol` to a `string` is allowed, but *implicit* coercion of the same is disallowed and throws an error.
Consider:

```
var s1 = Symbol( "cool" );
String( s1 );                                   // "Symbol(cool)"

var s2 = Symbol( "not cool" );
s2 + "";                                        // TypeError
```

`symbol` values cannot coerce to `number` at all (throws an error either way), but strangely they can both *explicitly* and *implicitly* coerce to `boolean` (always `true`).

Consistency is always easier to learn, and exceptions are never fun to deal with, but we just need to be careful around the new ES6 `symbol` values and how we coerce them.
The good news: it's probably going to be exceedingly rare for you to need to coerce a `symbol` value. The way they're typically used (see Chapter 3) will probably not call for coercion on a normal basis.

Loose Equals vs. Strict Equals

Loose equals is the `==` operator, and strict equals is the `===` operator. Both operators are used for comparing two values for "equality," but the "loose" vs. "strict" indicates a **very important** difference in behavior between the two, specifically in how they decide "equality."
A very common misconception about these two operators is: "`==` checks values for equality and `===` checks both values and types for equality." While that sounds nice and reasonable, it's inaccurate. Countless well-respected JavaScript books and blogs have said exactly that, but unfortunately they're all *wrong*.
The correct description is: "`==` allows coercion in the equality comparison and `===` disallows coercion."

Equality Performance

Stop and think about the difference between the first (inaccurate) explanation and this second (accurate) one.

In the first explanation, it seems obvious that `===` is *doing more work* than `==`, because it has to *also* check the type. In the second explanation, `==` is the one *doing more work* because it has to follow through the steps of coercion if the types are different.
Don't fall into the trap, as many have, of thinking this has anything to do with performance, though, as if `==` is going to be slower than `===` in any relevant way. While it's measurable that coercion does take *a little bit* of processing time, it's mere microseconds (yes, that's millionths of a second!).
If you're comparing two values of the same types, `==` and `===` use the identical algorithm, and so other than minor differences in engine implementation, they should do the same work.
If you're comparing two values of different types, the performance isn't the important factor. What you should be asking yourself is: when comparing these two values, do I want coercion or not?

If you want coercion, use `==` loose equality, but if you don't want coercion, use `===` strict equality.

Note: The implication here then is that both `==` and `===` check the types of their operands. The difference is in how they respond if the types don't match.

Abstract Equality

The `==` operator's behavior is defined as "The Abstract Equality Comparison Algorithm" in section 11.9.3 of the ES5 spec. What's listed there is a comprehensive but simple algorithm that explicitly states every possible combination of types, and how the coercions (if necessary) should happen for each combination.
Warning: When (*implicit*) coercion is maligned as being too complicated and too flawed to be a *useful good part*, it is these rules of "abstract equality" that are being condemned. Generally, they are said to be too complex and too unintuitive for developers to practically learn and use, and that they are prone more to causing bugs in JS programs than to enabling greater code readability. I believe this is a flawed premise -- that you readers are competent developers who write (and read and understand!) algorithms (aka code) all day long. So, what follows is a plain exposition of the "abstract equality" in simple terms. But I implore you to also read the ES5 spec section 11.9.3. I think you'll be surprised at just how reasonable it is.

Basically, the first clause (11.9.3.1) says, if the two values being compared are of the same type, they are simply and naturally compared via Identity as you'd expect. For example, `42` is only equal to `42`, and `"abc"` is only equal to `"abc"`.
Some minor exceptions to normal expectation to be aware of:

- `NaN` is never equal to itself (see Chapter 2)
- `+0` and `-0` are equal to each other (see Chapter 2)

The final provision in clause 11.9.3.1 is for `==` loose equality comparison with `object`s (including `function`s and `array`s). Two such values are only *equal* if they are both references to *the exact same value*. No coercion occurs here.
Note: The `===` strict equality comparison is defined identically to 11.9.3.1, including the provision about two `object` values. It's a very little known fact that **`==` and `===` behave identically** in the case where two `object`s are being compared!
The rest of the algorithm in 11.9.3 specifies that if you use `==` loose equality to compare two values of different types, one or both of the values will need to be *implicitly* coerced. This coercion happens so that both values eventually end up as the same type, which can then directly be compared for equality using simple value Identity.

Note: The `!=` loose not-equality operation is defined exactly as you'd expect, in that it's literally the `==` operation comparison performed in its entirety, then the negation of the result. The same goes for the `!==` strict not-equality operation.

Comparing: `string`s to `number`s

To illustrate `==` coercion, let's first build off the `string` and `number` examples earlier in this chapter:

```
var a = 42;
var b = "42";

a === b;// false
a == b;         // true
```

As we'd expect, `a === b` fails, because no coercion is allowed, and indeed the `42` and `"42"` values are different.

However, the second comparison `a == b` uses loose equality, which means that if the types happen to be different, the comparison algorithm will perform *implicit* coercion on one or both values.

But exactly what kind of coercion happens here? Does the `a` value of `42` become a `string`, or does the `b` value of `"42"` become a `number`?

In the ES5 spec, clauses 11.9.3.4-5 say:

4. If Type(x) is Number and Type(y) is String, return the result of the comparison x == ToNumber(y).
5. If Type(x) is String and Type(y) is Number, return the result of the comparison ToNumber(x) == y.

Warning: The spec uses `Number` and `String` as the formal names for the types, while this book prefers `number` and `string` for the primitive types. Do not let the capitalization of `Number` in the spec confuse you for the `Number()` native function. For our purposes, the capitalization of the type name is irrelevant -- they have basically the same meaning.

Clearly, the spec says the `"42"` value is coerced to a `number` for the comparison.

The *how* of that coercion has already been covered earlier, specifically with the `ToNumber` abstract operation. In this case, it's quite obvious then that the resulting two `42` values are equal.

Comparing: anything to `boolean`

One of the biggest gotchas with the *implicit* coercion of `==` loose equality pops up when you try to compare a value directly to `true` or `false`.

Consider:

```
var a = "42";
var b = true;

a == b; // false
```

Wait, what happened here!? We know that `"42"` is a truthy value (see earlier in this chapter). So, how come it's not `==` loose equal to `true`?
The reason is both simple and deceptively tricky. It's so easy to misunderstand, many JS developers never pay close enough attention to fully grasp it.

Let's again quote the spec, clauses 11.9.3.6-7:

6. If Type(x) is Boolean, return the result of the comparison ToNumber(x) == y.
7. If Type(y) is Boolean, return the result of the comparison x == ToNumber(y).

Let's break that down. First:

```
var x = true;
var y = "42";

x == y; // false
```

The `Type(x)` is indeed `Boolean`, so it performs `ToNumber(x)`, which coerces `true` to `1`. Now, `1 == "42"` is evaluated. The types are still different, so (essentially recursively) we reconsult the algorithm, which just as above will coerce `"42"` to `42`, and `1 == 42` is clearly `false`.
Reverse it, and we still get the same outcome:

```
var x = "42";
var y = false;

x == y; // false
```

The `Type(y)` is `Boolean` this time, so `ToNumber(y)` yields `0`. `"42" == 0` recursively becomes `42 == 0`, which is of course `false`.
In other words, **the value `"42"` is neither `== true` nor `== false`.** At first, that statement might seem crazy. How can a value be neither truthy nor falsy?
But that's the problem! You're asking the wrong question, entirely. It's not your fault, really. Your brain is tricking you.

`"42"` is indeed truthy, but `"42" == true` **is not performing a boolean test/coercion** at all, no matter what your brain says. `"42"` *is not* being coerced to a `boolean` (`true`), but instead `true` is being coerced to a `1`, and then `"42"` is being coerced to `42`.
Whether we like it or not, `ToBoolean` is not even involved here, so the truthiness or falsiness of `"42"` is irrelevant to the `==` operation!
What *is* relevant is to understand how the `==` comparison algorithm behaves with all the different type combinations. As it regards a `boolean` value on either side of the `==`, a `boolean` always coerces to a `number` *first*.
If that seems strange to you, you're not alone. I personally would recommend to never, ever, under any circumstances, use `== true` or `== false`. Ever.

But remember, I'm only talking about `==` here. `=== true` and `=== false` wouldn't allow the coercion, so they're safe from this hidden `ToNumber` coercion.
Consider:

```
var a = "42";

// bad (will fail!):
if (a == true) {
        // ..
}

// also bad (will fail!):
if (a === true) {
        // ..
}

// good enough (works implicitly):
if (a) {
        // ..
}

// better (works explicitly):
if (!!a) {
        // ..
}

// also great (works explicitly):
if (Boolean( a )) {
        // ..
}
```

If you avoid ever using `== true` or `== false` (aka loose equality with `boolean`s) in your code, you'll never have to worry about this truthiness/falsiness mental gotcha.

Comparing: `null`s to `undefined`s

Another example of *implicit* coercion can be seen with `==` loose equality between `null` and `undefined` values. Yet again quoting the ES5 spec, clauses 11.9.3.2-3:

2. If x is null and y is undefined, return true.
3. If x is undefined and y is null, return true.

`null` and `undefined`, when compared with `==` loose equality, equate to (aka coerce to) each other (as well as themselves, obviously), and no other values in the entire language. What this means is that `null` and `undefined` can be treated as indistinguishable for comparison purposes, if you use the `==` loose equality operator to allow their mutual *implicit* coercion.

```
var a = null;
var b;

a == b;          // true
```

```
a == null;       // true
b == null;       // true

a == false;      // false
b == false;      // false
a == "";// false
b == "";// false
a == 0;          // false
b == 0;          // false
```

The coercion between `null` and `undefined` is safe and predictable, and no other values can give false positives in such a check. I recommend using this coercion to allow `null` and `undefined` to be indistinguishable and thus treated as the same value. For example:

```
var a = doSomething();

if (a == null) {
        // ..
}
```

The `a == null` check will pass only if `doSomething()` returns either `null` or `undefined`, and will fail with any other value, even other falsy values like `0`, `false`, and `""`.
The *explicit* form of the check, which disallows any such coercion, is (I think) unnecessarily much uglier (and perhaps a tiny bit less performant!):

```
var a = doSomething();

if (a === undefined || a === null) {
        // ..
}
```

In my opinion, the form `a == null` is yet another example where *implicit* coercion improves code readability, but does so in a reliably safe way.

Comparing: `object`s to non-`object`s

If an `object`/`function`/`array` is compared to a simple scalar primitive (`string`, `number`, or `boolean`), the ES5 spec says in clauses 11.9.3.8-9:

8. If Type(x) is either String or Number and Type(y) is Object, return the result of the comparison x == ToPrimitive(y).
9. If Type(x) is Object and Type(y) is either String or Number, return the result of the comparison ToPrimitive(x) == y.

Note: You may notice that these clauses only mention `String` and `Number`, but not `Boolean`. That's because, as quoted earlier, clauses 11.9.3.6-7 take care of coercing any `Boolean` operand presented to a `Number` first.
Consider:

```
var a = 42;
var b = [ 42 ];

a == b;	// true
```

The `[ 42 ]` value has its `ToPrimitive` abstract operation called (see the "Abstract Value Operations" section earlier), which results in the `"42"` value. From there, it's just `42 == "42"`, which as we've already covered becomes `42 == 42`, so `a` and `b` are found to be coercively equal.
Tip: All the quirks of the `ToPrimitive` abstract operation that we discussed earlier in this chapter (`toString()`, `valueOf()`) apply here as you'd expect. This can be quite useful if you have a complex data structure that you want to define a custom `valueOf()` method on, to provide a simple value for equality comparison purposes.
In Chapter 3, we covered "unboxing," where an `object` wrapper around a primitive value (like from `new String("abc")`, for instance) is unwrapped, and the underlying primitive value (`"abc"`) is returned. This behavior is related to the `ToPrimitive` coercion in the `==` algorithm:

```
var a = "abc";
var b = Object( a );	// same as `new String( a )`

a === b;				// false
a == b;					// true
```

`a == b` is `true` because `b` is coerced (aka "unboxed," unwrapped) via `ToPrimitive` to its underlying `"abc"` simple scalar primitive value, which is the same as the value in `a`.
There are some values where this is not the case, though, because of other overriding rules in the `==` algorithm. Consider:

```
var a = null;
var b = Object( a );	// same as `Object()`
a == b;					// false

var c = undefined;
var d = Object( c );	// same as `Object()`
c == d;					// false

var e = NaN;
var f = Object( e );	// same as `new Number( e )`
e == f;					// false
```

The `null` and `undefined` values cannot be boxed -- they have no object wrapper equivalent -- so `Object(null)` is just like `Object()` in that both just produce a normal object.
`NaN` can be boxed to its `Number` object wrapper equivalent, but when `==` causes an unboxing, the `NaN == NaN` comparison fails because `NaN` is never equal to itself (see Chapter 2).

Edge Cases

Now that we've thoroughly examined how the *implicit* coercion of `==` loose equality works (in both sensible and surprising ways), let's try to call out the worst, craziest corner cases so we can see what we need to avoid to not get bitten with coercion bugs.
First, let's examine how modifying the built-in native prototypes can produce crazy results:

A Number By Any Other Value Would...

```
Number.prototype.valueOf = function() {
        return 3;
};

new Number( 2 ) == 3;    // true
```

Warning: `2 == 3` would not have fallen into this trap, because neither `2` nor `3` would have invoked the built-in `Number.prototype.valueOf()` method because both are already primitive `number` values and can be compared directly. However, `new Number(2)` must go through the `ToPrimitive` coercion, and thus invoke `valueOf()`.
Evil, huh? Of course it is. No one should ever do such a thing. The fact that you *can* do this is sometimes used as a criticism of coercion and `==`. But that's misdirected frustration. JavaScript is not *bad* because you can do such things, a developer is *bad* **if they do such things**. Don't fall into the "my programming language should protect me from myself" fallacy.
Next, let's consider another tricky example, which takes the evil from the previous example to another level:

```
if (a == 2 && a == 3) {
        // ..
}
```

You might think this would be impossible, because `a` could never be equal to both `2` and `3` *at the same time*. But "at the same time" is inaccurate, since the first expression `a == 2` happens strictly *before* `a == 3`.
So, what if we make `a.valueOf()` have side effects each time it's called, such that the first time it returns `2` and the second time it's called it returns `3`? Pretty easy:

```
var i = 2;

Number.prototype.valueOf = function() {
        return i++;
};

var a = new Number( 42 );

if (a == 2 && a == 3) {
        console.log( "Yep, this happened." );
}
```

Again, these are evil tricks. Don't do them. But also don't use them as complaints against coercion. Potential abuses of a mechanism are not sufficient evidence to condemn the mechanism. Just avoid these crazy tricks, and stick only with valid and proper usage of coercion.

False-y Comparisons

The most common complaint against *implicit* coercion in `==` comparisons comes from how falsy values behave surprisingly when compared to each other.
To illustrate, let's look at a list of the corner-cases around falsy value comparisons, to see which ones are reasonable and which are troublesome:

```
"0" == null;                     // false
"0" == undefined;                // false
"0" == false;                    // true -- UH OH!
"0" == NaN;                              // false
"0" == 0;                                // true
"0" == "";                               // false

false == null;                   // false
false == undefined;              // false
false == NaN;                    // false
false == 0;                              // true -- UH OH!
false == "";                     // true -- UH OH!
false == [];                     // true -- UH OH!
false == {};                     // false

"" == null;                              // false
"" == undefined;         // false
"" == NaN;                               // false
"" == 0;                         // true -- UH OH!
"" == [];                                // true -- UH OH!
"" == {};                                // false

0 == null;                               // false
0 == undefined;                  // false
0 == NaN;                                // false
0 == [];                         // true -- UH OH!
0 == {};                         // false
```

In this list of 24 comparisons, 17 of them are quite reasonable and predictable. For example, we know that `""` and `NaN` are not at all equatable values, and indeed they don't coerce to be loose equals, whereas `"0"` and `0` are reasonably equatable and *do* coerce as loose equals.
However, seven of the comparisons are marked with "UH OH!" because as false positives, they are much more likely gotchas that could trip you up. `""` and `0` are definitely distinctly different values, and it's rare you'd want to treat them as equatable, so their mutual coercion is troublesome. Note that there aren't any false negatives here.

The Crazy Ones

We don't have to stop there, though. We can keep looking for even more troublesome coercions:

```
[] == ![];              // true
```

Oooo, that seems at a higher level of crazy, right!? Your brain may likely trick you that you're comparing a truthy to a falsy value, so the `true` result is surprising, as we *know* a value can never be truthy and falsy at the same time!
But that's not what's actually happening. Let's break it down. What do we know about the `!` unary operator? It explicitly coerces to a `boolean` using the `ToBoolean` rules (and it also flips the parity). So before `[] == ![]` is even processed, it's actually already translated to `[] == false`. We already saw that form in our above list (`false == []`), so its surprise result is *not new* to us.
How about other corner cases?

```
2 == [2];               // true
"" == [null];    // true
```

As we said earlier in our `ToNumber` discussion, the right-hand side `[2]` and `[null]` values will go through a `ToPrimitive` coercion so they can be more readily compared to the simple primitives (`2` and `""`, respectively) on the left-hand side. Since the `valueOf()` for `array` values just returns the `array` itself, coercion falls to stringifying the `array`.
`[2]` will become `"2"`, which then is `ToNumber` coerced to `2` for the right-hand side value in the first comparison. `[null]` just straight becomes `""`.
So, `2 == 2` and `"" == ""` are completely understandable.
If your instinct is to still dislike these results, your frustration is not actually with coercion like you probably think it is. It's actually a complaint against the default `array` values' `ToPrimitive` behavior of coercing to a `string` value. More likely, you'd just wish that `[2].toString()` didn't return `"2"`, or that `[null].toString()` didn't return `""`.
But what exactly *should* these `string` coercions result in? I can't really think of any other appropriate `string` coercion of `[2]` than `"2"`, except perhaps `"[2]"` -- but that could be very strange in other contexts!
You could rightly make the case that since `String(null)` becomes `"null"`, then `String([null])` should also become `"null"`. That's a reasonable assertion. So, that's the real culprit.
Implicit coercion itself isn't the evil here. Even an *explicit* coercion of `[null]` to a `string` results in `""`. What's at odds is whether it's sensible at all for `array` values to stringify to the equivalent of their contents, and exactly how that happens. So, direct your frustration at the rules for `String( [..] )`, because that's where the craziness stems

from. Perhaps there should be no stringification coercion of `array`s at all? But that would have lots of other downsides in other parts of the language.
Another famously cited gotcha:

```
0 == "\n";                // true
```

As we discussed earlier with empty `""`, `"\n"` (or `" "` or any other whitespace combination) is coerced via `ToNumber`, and the result is `0`. What other `number` value would you expect whitespace to coerce to? Does it bother you that *explicit* `Number(" ")` yields `0`?
Really the only other reasonable `number` value that empty strings or whitespace strings could coerce to is the `NaN`. But would that *really* be better? The comparison `" " == NaN` would of course fail, but it's unclear that we'd have really *fixed* any of the underlying concerns.
The chances that a real-world JS program fails because `0 == "\n"` are awfully rare, and such corner cases are easy to avoid.
Type conversions **always** have corner cases, in any language -- nothing specific to coercion. The issues here are about second-guessing a certain set of corner cases (and perhaps rightly so!?), but that's not a salient argument against the overall coercion mechanism.

Bottom line: almost any crazy coercion between *normal values* that you're likely to run into (aside from intentionally tricky `valueOf()` or `toString()` hacks as earlier) will boil down to the short seven-item list of gotcha coercions we've identified above.
To contrast against these 24 likely suspects for coercion gotchas, consider another list like this:

```
42 == "43";                                                 // false
"foo" == 42;                                        // false
"true" == true;                                     // false

42 == "42";                                                 // true
"foo" == [ "foo" ];                                 // true
```

In these nonfalsy, noncorner cases (and there are literally an infinite number of comparisons we could put on this list), the coercion results are totally safe, reasonable, and explainable.

Sanity Check

OK, we've definitely found some crazy stuff when we've looked deeply into *implicit* coercion. No wonder that most developers claim coercion is evil and should be avoided, right!?

But let's take a step back and do a sanity check.

By way of magnitude comparison, we have *a list* of seven troublesome gotcha coercions, but we have *another list* of (at least 17, but actually infinite) coercions that are totally sane and explainable.

If you're looking for a textbook example of "throwing the baby out with the bathwater," this is it: discarding the entirety of coercion (the infinitely large list of safe and useful behaviors) because of a list of literally just seven gotchas.

The more prudent reaction would be to ask, "how can I use the countless *good parts* of coercion, but avoid the few *bad parts*?"

Let's look again at the *bad* list:

```
"0" == false;                   // true -- UH OH!
false == 0;                             // true -- UH OH!
false == "";                    // true -- UH OH!
false == [];                    // true -- UH OH!
"" == 0;                        // true -- UH OH!
"" == [];                               // true -- UH OH!
0 == [];                        // true -- UH OH!
```

Four of the seven items on this list involve `== false` comparison, which we said earlier you should **always, always** avoid. That's a pretty easy rule to remember.
Now the list is down to three.

```
"" == 0;                        // true -- UH OH!
"" == [];                               // true -- UH OH!
0 == [];                        // true -- UH OH!
```

Are these reasonable coercions you'd do in a normal JavaScript program? Under what conditions would they really happen?

I don't think it's terribly likely that you'd literally use `== []` in a `boolean` test in your program, at least not if you know what you're doing. You'd probably instead be doing `== ""` or `== 0`, like:

```
function doSomething(a) {
        if (a == "") {
                // ..
        }
}
```

You'd have an oops if you accidentally called `doSomething(0)` or `doSomething([])`. Another scenario:

```
function doSomething(a,b) {
        if (a == b) {
                // ..
        }
}
```

Again, this could break if you did something like `doSomething("",0)` or `doSomething([],"")`.
So, while the situations *can* exist where these coercions will bite you, and you'll want to be careful around them, they're probably not super common on the whole of your code base.

Safely Using Implicit Coercion

The most important advice I can give you: examine your program and reason about what values can show up on either side of an `==` comparison. To effectively avoid issues with such comparisons, here's some heuristic rules to follow:

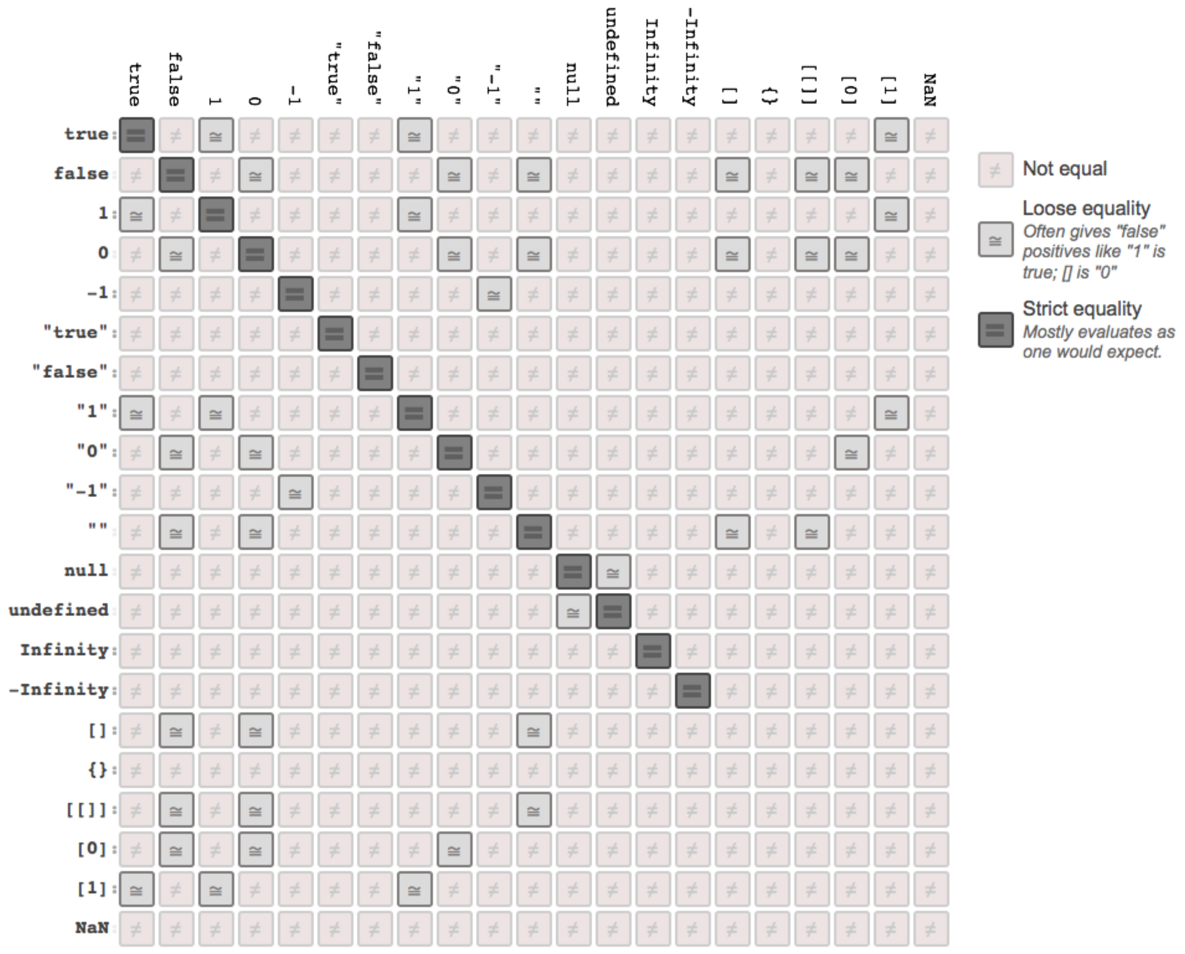
1. If either side of the comparison can have `true` or `false` values, don't ever, EVER use `==`.
2. If either side of the comparison can have `[]`, `""`, or `0` values, seriously consider not using `==`.

In these scenarios, it's almost certainly better to use `===` instead of `==`, to avoid unwanted coercion. Follow those two simple rules and pretty much all the coercion gotchas that could reasonably hurt you will effectively be avoided.
Being more explicit/verbose in these cases will save you from a lot of headaches.

The question of `==` vs. `===` is really appropriately framed as: should you allow coercion for a comparison or not?
There's lots of cases where such coercion can be helpful, allowing you to more tersely express some comparison logic (like with `null` and `undefined`, for example).
In the overall scheme of things, there's relatively few cases where *implicit* coercion is truly dangerous. But in those places, for safety sake, definitely use `===`.
Tip: Another place where coercion is guaranteed *not* to bite you is with the `typeof` operator. `typeof` is always going to return you one of seven strings (see Chapter 1), and none of them are the empty `""` string. As such, there's no case where checking the type of some value is going to run afoul of *implicit* coercion. `typeof x == "function"` is 100% as safe and reliable as `typeof x === "function"`. Literally, the spec says the algorithm will be identical in this situation. So, don't just blindly use `===` everywhere simply because that's what your code tools tell you to do, or (worst of all) because you've been told in some book to **not think about it**. You own the quality of your code.
Is *implicit* coercion evil and dangerous? In a few cases, yes, but overwhelmingly, no.

Be a responsible and mature developer. Learn how to use the power of coercion (both *explicit* and *implicit*) effectively and safely. And teach those around you to do the same.

Here's a handy table made by Alex Dorey (@dorey on GitHub) to visualize a variety of comparisons:



	true	false	1	0	-1	"true"	"false"	"1"	"0"	"-1"	""	null	undefined	Infinity	-Infinity	[]	{}	[[]]	[0]	[1]	NaN
true	=	≠	≅	≠	≠	≠	≠	≅	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≅	≠
false	≠	=	≠	≅	≠	≠	≠	≠	≅	≠	≅	≠	≠	≠	≠	≅	≠	≅	≅	≠	≠
1	≅	≠	=	≠	≠	≠	≠	≅	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≅	≠
0	≠	≅	≠	=	≠	≠	≠	≠	≅	≠	≅	≠	≠	≠	≠	≅	≠	≅	≅	≠	≠
-1	≠	≠	≠	≠	=	≠	≠	≠	≠	≅	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
"true"	≠	≠	≠	≠	≠	=	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
"false"	≠	≠	≠	≠	≠	≠	=	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
"1"	≅	≠	≅	≠	≠	≠	≠	=	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≅	≠
"0"	≠	≅	≠	≅	≠	≠	≠	≠	=	≠	≠	≠	≠	≠	≠	≠	≠	≠	≅	≠	≠
"-1"	≠	≠	≠	≠	≅	≠	≠	≠	≠	=	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
""	≠	≅	≠	≅	≠	≠	≠	≠	≠	≠	=	≠	≠	≠	≠	≅	≠	≅	≠	≠	≠
null	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	=	≅	≠	≠	≠	≠	≠	≠	≠	≠
undefined	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≅	=	≠	≠	≠	≠	≠	≠	≠	≠
Infinity	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	=	≠	≠	≠	≠	≠	≠	≠
-Infinity	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	=	≠	≠	≠	≠	≠	≠
[]	≠	≅	≠	≅	≠	≠	≠	≠	≠	≠	≅	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
{}	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
[[]]	≠	≅	≠	≅	≠	≠	≠	≠	≠	≠	≅	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
[0]	≠	≅	≠	≅	≠	≠	≠	≠	≅	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
[1]	≅	≠	≅	≠	≠	≠	≠	≅	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠
NaN	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠	≠

≠ Not equal

≅ Loose equality
Often gives "false" positives like "1" is true; [] is "0"

= Strict equality
Mostly evaluates as one would expect.

Source: https://github.com/dorey/JavaScript-Equality-Table

Abstract Relational Comparison

While this part of *implicit* coercion often gets a lot less attention, it's important nonetheless to think about what happens with `a < b` comparisons (similar to how we just examined `a == b` in depth).
The "Abstract Relational Comparison" algorithm in ES5 section 11.8.5 essentially divides itself into two parts: what to do if the comparison involves both `string` values (second half), or anything else (first half).

Note: The algorithm is only defined for `a < b`. So, `a > b` is handled as `b < a`.
The algorithm first calls `ToPrimitive` coercion on both values, and if the return result of either call is not a `string`, then both values are coerced to `number` values using the `ToNumber` operation rules, and compared numerically.
For example:

```
var a = [ 42 ];
var b = [ "43" ];

a < b;  // true
b < a;  // false
```

Note: Similar caveats for `-0` and `NaN` apply here as they did in the `==` algorithm discussed earlier.
However, if both values are `string`s for the `<` comparison, simple lexicographic (natural alphabetic) comparison on the characters is performed:

```
var a = [ "42" ];
var b = [ "043" ];

a < b;  // false
```

`a` and `b` are *not* coerced to `number`s, because both of them end up as `string`s after the `ToPrimitive` coercion on the two `array`s. So, `"42"` is compared character by character to `"043"`, starting with the first characters `"4"` and `"0"`, respectively. Since `"0"` is lexicographically *less than* than `"4"`, the comparison returns `false`.
The exact same behavior and reasoning goes for:

```
var a = [ 4, 2 ];
var b = [ 0, 4, 3 ];

a < b;  // false
```

Here, `a` becomes `"4,2"` and `b` becomes `"0,4,3"`, and those lexicographically compare identically to the previous snippet.
What about:

```
var a = { b: 42 };
var b = { b: 43 };

a < b;  // ??
```

`a < b` is also `false`, because `a` becomes `[object Object]` and `b` becomes `[object Object]`, and so clearly `a` is not lexicographically less than `b`.
But strangely:

```
var a = { b: 42 };
var b = { b: 43 };

a < b;  // false
```

```
a == b; // false
a > b;  // false

a <= b; // true
a >= b; // true
```

Why is `a == b` not `true`? They're the same `string` value (`"[object Object]"`), so it seems they should be equal, right? Nope. Recall the previous discussion about how `==` works with `object` references.
But then how are `a <= b` and `a >= b` resulting in `true`, if `a < b` **and** `a == b` **and** `a > b` are all `false`?
Because the spec says for `a <= b`, it will actually evaluate `b < a` first, and then negate that result. Since `b < a` is *also* `false`, the result of `a <= b` is `true`.
That's probably awfully contrary to how you might have explained what `<=` does up to now, which would likely have been the literal: "less than *or* equal to." JS more accurately considers `<=` as "not greater than" (`!(a > b)`, which JS treats as `!(b < a)`). Moreover, `a >= b` is explained by first considering it as `b <= a`, and then applying the same reasoning.
Unfortunately, there is no "strict relational comparison" as there is for equality. In other words, there's no way to prevent *implicit* coercion from occurring with relational comparisons like `a < b`, other than to ensure that `a` and `b` are of the same type explicitly before making the comparison.
Use the same reasoning from our earlier `==` vs. `===` sanity check discussion. If coercion is helpful and reasonably safe, like in a `42 < "43"` comparison, **use it**. On the other hand, if you need to be safe about a relational comparison, *explicitly coerce* the values first, before using `<` (or its counterparts).
```
var a = [ 42 ];
var b = "043";

a < b;                                      // false -- string comparison!
Number( a ) < Number( b );       // true -- number comparison!
```

Review

In this chapter, we turned our attention to how JavaScript type conversions happen, called **coercion**, which can be characterized as either *explicit* or *implicit*.

Coercion gets a bad rap, but it's actually quite useful in many cases. An important task for the responsible JS developer is to take the time to learn all the ins and outs of coercion to decide which parts will help improve their code, and which parts they really should avoid.

Explicit coercion is code which is obvious that the intent is to convert a value from one type to another. The benefit is improvement in readability and maintainability of code by reducing confusion.

Implicit coercion is coercion that is "hidden" as a side-effect of some other operation, where it's not as obvious that the type conversion will occur. While it may seem that *implicit* coercion is the opposite of *explicit* and is thus bad (and indeed, many think so!), actually *implicit* coercion is also about improving the readability of code.

Especially for *implicit*, coercion must be used responsibly and consciously. Know why you're writing the code you're writing, and how it works. Strive to write code that others will easily be able to learn from and understand as well.