



JavaScript Spessore

A Thick Shot of Objects, Metaobjects, & Protocols
by Reginald “raganwald” Braithwaite

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Reginald Braithwaite

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Prefaces



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Taking a page out of LiSP

Teaching Lisp by implementing Lisp is a long-standing tradition. We read book after book, lecture after lecture, blog post after blog post, all explaining how to implement Lisp in Lisp. Christian Queinnec's [Lisp in Small Pieces](#)² ("LiSP") is particularly notable, not just implementing a Lisp in Lisp, but covering a wide range of different semantics within Lisp.

LiSP's approach is to introduce a feature of Lisp, then develop an implementation. The book covers [Lisp-1 vs. Lisp-2³, then discusses how to implement namespaces, building a simple Lisp-1 and a simple Lisp-2. Another chapter discusses scoping, and again you build interpreters for dynamic and block scoped Lisps.

Building interpreters (and eventually compilers) may seem esoteric compared to tutorials demonstrating how to build a blogging engine, but there's a method to this madness. If you implement block scoping in a "toy" language, you gain a deep understanding of how closures really work in any language. If you write a Lisp that rewrites function calls in [Continuation Passing Style](#)⁴, you can't help but feel comfortable using JavaScript callbacks in [Node.js](#)⁵.

Implementing a language feature teaches you a tremendous amount about how the feature works in a relatively short amount of time. And that goes double for implementing variations on the same feature—like dynamic vs block scoping or single vs multiple namespaces.

In this book, we are going to implement a number of different programming language semantics, all in JavaScript. We won't be choosing features at random; We aren't going to try to implement every possible type of programming language semantics. We won't explore dynamic vs block scoping, we won't implement call-by-name, and we will ignore the temptation to experiment with lazy evaluation.

We *are* going to implement different object semantics, implement different kinds of metaobjects, and implement different kinds of method protocols. We are going to focus on the semantics of objects, metaobjects, and protocols, because we're interested in understanding "object-oriented programming" and all of its rich possibilities.

In doing so, we'll learn about the principles of object-oriented programming in far more depth than we would if we chose to implement a "practical" example like a blogging engine.

²http://www.amazon.com/gp/product/B00AKE1U6O/ref=as_li_ss_til?ie=UTF8&camp=1789&creative=390957&creativeASIN=B00AKE1U6O&linkCode=as2&tag=raganwald001-20

³A "Lisp-1" has a single namespace for both functions and other values. A "Lisp-2" has separate namespaces for functions and other values. To the extend that JavaScript resembles a Lisp, it resembles a Lisp-1. See [The function namespace](#).

⁴https://en.wikipedia.org/wiki/Continuation-passing_style

⁵<http://nodejs.org/about/>

JavaScript Allongé and `allong.es`

JavaScript Spessore⁶ is written for the reader who has read [JavaScript Allongé](#)⁷ or has equivalent experience with JavaScript, especially as it pertains to functions, closures, and prototypes. JavaScript Allongé is well-regarded amongst programmers:

“This is a must-read for any developer who wants to know Javascript better... Reg has a way of explaining things in a way that connected the dots for me. This is probably the only programming book I’ve re-read cover to cover a dozen times or more.”—etrinh

“I think it’s one of the best tech books I’ve read since Sedgewick’s Algorithms in C.”—Andrey Sidorov

“Your explanation of closures in JavaScript Allongé is the best I’ve read.”—Emehrkay

“It’s a different approach to JavaScript than you’ll find in most other places and shines a light on some of the more elegant parts of JavaScript the language.”—@jeremymorrell

Even if you know the material, you may want to read JavaScript Allongé to familiarize yourself its approach to functional combinators. You can [read it for free online](#)⁸.

`allong.es`

[allong.es](#)⁹ is a JavaScript library inspired by JavaScript Allongé. It contains many utility functions that are used in JavaScript Spessore’s examples, such as `map`, `variadic` and `tap`. It’s free, and you can even type a lot of the examples from this book into its [try allong.es](#)¹⁰ page and see them work.

⁶<https://leanpub.com/javascript-spessore>

⁷<https://leanpub.com/javascript-allonge>

⁸<https://leanpub.com/javascript-allonge/read>

⁹<http://allong.es>

¹⁰<http://allong.es/try/>

Disclaimer

Writing is a journey, not a destination. This sample documents the direction we're facing as we take the next step.

This sample “document” is provided to illustrate direction [JavaScript Spessore¹¹](#) is taking. **It is not held out to contain any of the actual book’s content.** “Purchases” are being offered to people whose primary motivation is to support the book and encourage me to get it done.

Your purchase does include the right to download any and all versions of the book, as per Leanpub’s lean publishing model. You will never be asked to pay more. You have the right to a 100% no-questions-asked refund if you are not satisfied with the progress of the book:

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That being said, writing like this cannot be rushed: progress may be slow relative to a “Learn JavaScript OO in 21 Days” type of book. If you would prefer that there be a substantial amount of work completed, please be patient and check back in a month or so.

Please also bear in mind that pricing and bundling may vary over time. The book may be offered at any price in the future or even be free to read or free to share at some point in the future.

¹¹<https://leanpub.com/javascript-spessore>

¹²<https://leanpub.com/terms#returns>

The Object's The Thing



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A Smalltalk object can do exactly three things: Hold state (references to other objects), receive a message from itself or another object, and in the course of processing a message, send messages to itself or another object.—[Smalltalk on Wikipedia](#)¹⁴

Objects seem simple enough: They hold state, they receive messages, they process those messages, and in the course of processing messages, they also send messages. This brief definition implies an important idea: Objects can *change state* in the course of processing messages. They do this directly by removing, changing, or adding to the references they hold.

¹³Londinium 1 Lever Espresso Machine (c) 2013 Alejandro Erickson, some rights reserved

¹⁴<https://en.wikipedia.org/wiki/Smalltalk>

messages and method invocations



A nine year-old messenger boy

Smalltalk speaks of “messages.” The metaphor of a message is very clear. A message is composed and sent from one entity (the “sender”) to one entity (the “recipient”). The sender specifies the identity of the recipient. The message may contain information for the recipient, instructions to perform some task, or a question to be answered. An immediate reply may be requested, or the sender may trust the message’s recipient to act appropriately. The metaphor of the “message” emphasizes the arms-length relationship between sender and recipient.¹⁵

Popular languages don’t usually discuss messages. Instead, they speak of “invoking methods.” Invoking a method has a much more imperative implication than “sending a message.” It implies that the entity doing the invoking is causing something to happen, even if the precise implementation is the receiver’s responsibility. Most popular languages are synchronous: The code that invokes the method waits for a response.

methods

A method is a kind of recipe for handling a message. In JavaScript, methods are functions. In other languages, methods are a separate kind of thing than functions. In many languages, the namespace for methods is distinct from the namespace for instance variables and other internal references. In JavaScript, methods and internal state are stored together as properties by default.

If we wish to organize methods separately from internal state, we must impose our own structure.

¹⁵More exotic messaging protocols are possible. Instead of a message being couriered from one entity to another entity, it could be posted on a public or semi-private space where many recipients could view it and decide for themselves whether to respond. Or perhaps there is a dispatching entity that examines each message and decides who ought to respond, much as an operator might direct your call to the right person within an organization.

references and state

You can imagine sending a message to a mathematician: “What’s the biggest number: one, five, or four?” You can do that in JavaScript:

```
Math.max(1, 5, 4)  
//=> 5
```

Although this is a message, it is unsatisfying to think of `Math` as an object, because it doesn’t have any state. Objects were invented fifty years ago¹⁶ to model entities when building simulations. When making a simulation, an essential design technique is to make provide entity with its own independent decision-making ability.

Let’s say we’re modeling traffic. In real life, each car has its own characteristics like maximum speed. Each car has a driver with their own particular style of driving, and of course different cars have different destinations and perhaps different senses of urgency. Each driver independently responds to the local situation around their car. The same goes for traffic lights, roads... Everything has its own independent behavior.

The way to build a simulation is to provide each simulated entity such as the cars, roads, and traffic lights, with their own little programs. You then embed them in a simulated city with a supervisory program doling out events such as rain. Finally, you start the simulation and see what happens.

The key need is to be able to have entities be independent decision-making units that respond to events from outside of themselves. In essence, we’re describing computing units. Computation has, at its heart, a program and some kind of storage representing its state. Although impractical, each entity in a simulation could be a Turing Machine with a long tape.

And thus when we think of “objects,” we think of independent computing devices, each with their own storage representing their state: **An object is an entity that uses handlers to respond to messages. It maintains internal state, and its handlers are responsible for querying and/or updating its state.**

¹⁶<https://en.wikipedia.org/wiki/Simula> “The Simula Programming Language”

Objects, Revisited

coming soon

Immutable Properties

Sometimes we want to share objects by reference for performance and space reasons, but we don't want them to be mutable. One motivation is when we want many objects to be able to share a common entity without worrying that one of them may inadvertently change the common entity.

JavaScript provides a way to make properties immutable:

```
"use strict";  
  
var rentAmount = {};  
  
Object.defineProperty(rentAmount, 'dollars', {  
  enumerable: true,  
  writable: false,  
  value: 420  
});  
  
Object.defineProperty(rentAmount, 'cents', {  
  enumerable: true,  
  writable: false,  
  value: 0  
});  
  
rentAmount.dollars  
//=> 420  
  
rentAmount.dollars = 600;  
//=> 600  
  
rentAmount.dollars  
//=> 420
```

`Object.defineProperty` is a general-purpose method for providing fine-grained control over the properties of any object. When we make a property `enumerable`, it shows up whenever we list the object's properties or iterate over them. When we make it `writable`, assignments to the property change its value. If the property isn't `writable`, assignments are ignored.

When we want to define multiple properties, we can also write:

```

var rentAmount = {};

Object.defineProperties(rentAmount, {
  dollars: {
    enumerable: true,
    writable: false,
    value: 420
  },
  cents: {
    enumerable: true,
    writable: false,
    value: 0
  }
});

rentAmount.dollars
//=> 420

rentAmount.dollars = 600;
//=> 600

rentAmount.dollars
//=> 420

```

While we can't make the entire object immutable, we can define the properties we want to be immutable. Naturally, we can generalize this:

```

function immutable (propertiesAndValues) {
  return tap({}, function (object) {
    for (var key in propertiesAndValues) {
      if (propertiesAndValues.hasOwnProperty(key)) {
        Object.defineProperty(object, key, {
          enumerable: true,
          writable: false,
          value: propertiesAndValues[key]
        });
      }
    }
  });
}

var rentAmount = immutable({

```

```
    dollars: 420,  
    cents: 0  
});  
  
rentAmount.dollars  
//=> 420  
  
rentAmount.dollars = 600;  
//=> 600  
  
rentAmount.dollars  
//=> 420
```

considerations

As a means for protecting our data structures from inadvertent modification, this “silent failure” isn’t great, but it at least *localizes* the failure mode to the objects our code is trying to change, and not to objects that may be sharing an object we’re trying to change.

But it does force us to test property assignments. Whenever you write some code like this:

```
rentCheque.amount.dollars = 600;
```

You ought to write a test case that checks to see whether the cheque’s dollar figure really changed. And now that you know that immutable properties are a JavaScript feature, you really need to check assignments whether you’re using them or not. Who knows what changes might be made to your code in the future? Testing assignments ensures that you will catch any regressions that might be caused in the future.

Copy On Write Semantics

Coming Soon

Accessors

The Java and Ruby folks are very comfortable with a general practice of not allowing objects to modify each other's properties. They prefer to write *getters and setters*, functions that do the getting and setting. If we followed this practice, we might write:

```
var mutableAmount = (function () {
  var _dollars = 0;
  var _cents = 0;
  return immutable({
    setDollars: function (amount) {
      return (_dollars = amount);
    },
    getDollars: function () {
      return _dollars;
    },
    setCents: function (amount) {
      return (_cents = amount);
    },
    getCents: function () {
      return _cents;
    }
  });
})();

mutableAmount.getDollars()
//=> 0

mutableAmount.setDollars(420);

mutableAmount.getDollars()
//=> 420
```

We've put functions in the object for getting and setting values, and we've hidden the values themselves in a *closure*, the environment of an [Immediately Invoked Function Expression¹⁷](#) ("IIFE").

Of course, this amount can still be mutated, but we are now mediating access with functions. We could, for example, enforce certain validity rules:

¹⁷https://en.wikipedia.org/wiki/Immediately-invoked_function_expression

```

var mutableAmount = (function () {
  var _dollars = 0;
  var _cents = 0;
  return immutable({
    setDollars: function (amount) {
      if (amount >= 0 && amount === Math.floor(amount))
        return (_dollars = amount);
    },
    getDollars: function () {
      return _dollars;
    },
    setCents: function (amount) {
      if (amount >= 0 && amount < 100 && amount === Math.floor(amount))
        return (_cents = amount);
    },
    getCents: function () {
      return _cents;
    }
  });
})();

mutableAmount.setDollars(-5)
//=> undefined

mutableAmount.getDollars()
//=> 0

```

Immutability is easy, just leave out the “getters:”

```

var rentAmount = (function () {
  var _dollars = 420;
  var _cents = 0;
  return immutable({
    getDollars: function () {
      return _dollars;
    },
    getCents: function () {
      return _cents;
    }
  });
})();

```

```
mutableAmount.setDollars(-5)
//=> undefined
```

```
mutableAmount.getDollars()
//=> 0
```

using accessors for properties

Languages like Ruby allow you to write code that looks like you're doing direct access of properties but still mediate access with functions. JavaScript allows this as well. Let's revisit `Object.defineProperties`:

```
var mediatedAmount = (function () {
  var _dollars = 0;
  var _cents = 0;
  var amount = {};
  Object.defineProperties(amount, {
    dollars: {
      enumerable: true,
      set: function (amount) {
        if (amount >= 0 && amount === Math.floor(amount))
          return (_dollars = amount);
      },
      get: function () {
        return _dollars;
      }
    },
    cents: {
      enumerable: true,
      set: function (amount) {
        if (amount >= 0 && amount < 100 && amount === Math.floor(amount))
          return (_cents = amount);
      },
      get: function () {
        return _cents;
      }
    }
  });
  return amount;
})();
//=>
{ dollars: [Getter/Setter],
```

```

cents: [Getter/Setter] }

mediatedAmount.dollars = 600;

mediatedAmount.dollars
//=> 600

mediatedAmount.cents = 33.5

mediatedAmount.cents
//=> 0

```

We can leave out the setters if we wish:

```

var mediatedImmutableAmount = (function () {
  var _dollars = 420;
  var _cents = 0;
  var amount = {};
  Object.defineProperties(amount, {
    dollars: {
      enumerable: true,
      get: function () {
        return _dollars;
      }
    },
    cents: {
      enumerable: true,
      get: function () {
        return _cents;
      }
    }
  });
  return amount;
})();

mediatedImmutableAmount.dollars = 600;

mediatedImmutableAmount.dollars
//=> 420

```

Once again, the failure is silent. Of course, we can change that:

```
var noisyAmount = (function () {
  var _dollars = 0;
  var _cents = 0;
  var amount = {};
  Object.defineProperties(amount, {
    dollars: {
      enumerable: true,
      set: function (amount) {
        if (amount !== _dollars)
          throw new Error("You can't change that!");
      },
      get: function () {
        return _dollars;
      }
    },
    cents: {
      enumerable: true,
      set: function (amount) {
        if (amount !== _cents)
          throw new Error("You can't change that!");
      },
      get: function () {
        return _cents;
      }
    }
  });
  return amount;
})();

noisyAmount.dollars = 500
//=> Error: You can't change that!
```

Hiding Object Properties

Many “OO” programming languages have the notion of private instance variables, properties that cannot be accessed by other entities. JavaScript has no such notion, we have to use specific techniques to create the illusion of private state for objects.

enumerability

In JavaScript, there is only one kind of “privacy” for properties. But it’s not what you expect. When an object has properties, you can access them with the dot notation, like this:

```
var dictionary = {  
    abstraction: "an abstract or general idea or term",  
    encapsulate: "to place in or as if in a capsule",  
    object: "anything that is visible or tangible and is relatively stable in form"  
};  
  
dictionary.encapsulate  
//=> 'to place in or as if in a capsule'
```

You can also access properties indirectly through the use of [] notation and the value of an expression:

```
dictionary[abstraction]  
//=> ReferenceError: abstraction is not defined
```

Whoops, the value of an *expression*: The expression `abstraction` looks up the value associated with the variable “abstraction.” Alas, such a variable hasn’t been defined in this code, so that’s an error. This works, because ‘`abstraction`’ is an expression that evaluates to the string we want:

```
dictionary['abstraction']  
//=> 'an abstract or general idea or term'
```

One kind of privacy concerns who has access to properties. In JavaScript, all code has access to all properties of every object. There is no way to create a property of an object such that some functions can access it and others cannot.

So what kind of privacy does JavaScript provide? In order to access a property, you have to know its name. If you don’t know the names of an object’s properties, you can access the names in several ways. Here’s one:

```
Object.keys(dictionary)
//=>
[ 'abstraction',
  'encapsulate',
  'object' ]
```

This is called *enumerating* an object's properties. Not only are they "public" in the sense that any code that knows the property's names can access it, but also, any code at all can enumerate them. You can do neat things with enumerable properties, such as:

```
var descriptor = map(Object.keys(dictionary), function (key) {
  return key + ': "' + dictionary[key] + '"';
}).join('; ');

descriptor
//=>
'abstraction: "an abstract or general idea or term"; encapsulate: "to place i\
n or as if in a
  capsule"; object: "anything that is visible or tangible and is relatively sta\
ble in form"'
```

So, our three properties are *accessible* and also *enumerable*. Are there any properties that are accessible, but not enumerable? There sure can be. You recall that we can define properties using `Object.defineProperty`. One of the options is called, appropriately enough, `enumerable`.

Let's define a getter that isn't enumerable:

```
Object.defineProperty(dictionary, 'length', {
  enumerable: false,
  get: function () {
    return Object.keys(this).length
  }
});

dictionary.length
//=> 3
```

Notice that `length` obviously isn't included in `Object.keys`, otherwise our little getter would return 4, not 3. And it doesn't affect our little descriptor expression, let's evaluate it again:

```
map(Object.keys(dictionary), function (key) {
  return key + ': "' + dictionary[key] + '"';
}).join('; ')
//=>
  'abstraction: "an abstract or general idea or term"; encapsulate: "to place i\
n or as if in a
  capsule"; object: "anything that is visible or tangible and is relatively sta\
ble in form"'
```

Non-enumerable properties don't have to be getters:

```
Object.defineProperty(dictionary, 'secret', {
  enumerable: false,
  writable: true,
  value: "kept from the knowledge of any but the initiated or privileged"
});

dictionary.secret
//=> 'kept from the knowledge of any but the initiated or privileged'

dictionary.length
//=> 3
```

`secret` is indeed a secret. It's fully accessible if you know it's there, but it's not enumerable, so it doesn't show up in `Object.keys`.

One way to “hide” properties in JavaScript is to define them as properties with `enumerable: false`.

closures

We saw earlier that it is possible to fake private instance variables by hiding references in a closure, e.g.

```
function immutable (propertiesAndValues) {
  return tap({}, function (object) {
    for (var key in propertiesAndValues) {
      if (propertiesAndValues.hasOwnProperty(key)) {
        Object.defineProperty(object, key, {
          enumerable: true,
          writable: false,
          value: propertiesAndValues[key]
        });
      }
    }
  });
}
```

```

        }
    }
});
}

var rentAmount = (function () {
    var _dollars = 420;
    var _cents = 0;
    return immutable({
        dollars: function () {
            return _dollars;
        },
        cents: function () {
            return _cents;
        }
    });
})();

```

`_dollars` and `_cents` aren't properties of the `rentAmount` object at all, they're variables within the environment of an IIFE. The functions associated with `dollars` and `cents` are within its scope, so they have access to its variables.

This has some obvious space and performance implications. There's also the general problem that an environment like a closure is its own thing in JavaScript that exists outside of the language's usual features. For example, you can iterate over the enumerable properties of an object, but you can't iterate over the variables being used inside of an object's functions. Another example: you can access a property indirectly with `[expression]`. You can't access a closure's variable indirectly without some clever finagling using `eval`.

Finally, there's another very real problem: Each and every function belonging to each and every object must be a distinct entity in JavaScript's memory. Let's make another amount using the same pattern as above:

```

var rentAmount2 = (function () {
    var _dollars = 600;
    var _cents = 0;
    return immutable({
        dollars: function () {
            return _dollars;
        },
        cents: function () {
            return _cents;
        }
    });
})();

```

```
});  
})();
```

We now have defined four functions: Two getters for `rentAmount`, and two for `rentAmount2`. Although the two `dollars` functions have identical code, they're completely different entities to JavaScript because each has a different enclosing environment. The same thing goes for the two `cents` functions. In the end, we're going to create an enclosing environment and two new functions every time we create an amount using this pattern.

naming conventions

Let's compare this to a different approach. We'll write almost the identical code, but we'll rely on a naming convention to hide our values in plain sight:

```
function dollars () {  
  return this._dollars;  
}  
  
function cents () {  
  return this._cents;  
}  
  
var rentAmount = immutable({  
  dollars: dollars,  
  cents: cents  
});  
rentAmount._dollars = 420;  
rentAmount._cents = 0;
```

Our convention is that other entities should not modify any property that has a name beginning with `_`. There's no enforcement, it's just a practice. Other entities can use getters and setters. We've created two functions, and we're using `this` to make sure they refer to the object's environment. With this pattern, we need two functions and one object to represent an amount.

One problem with this approach, of course, is that everything we're using is enumerable:

```
Object.keys(rentAmount)
//=>
[ 'dollars',
  'cents',
  '_dollars',
  '_cents' ]
```

We'd better fix that:

```
Object.defineProperties(rentAmount, {
  _dollars: {
    enumerable: false,
    writable: true
  },
  _cents: {
    enumerable: false,
    writable: true
  }
});
```

Let's create another amount:

```
var raisedAmount = immutable({
  dollars: dollars,
  cents: cents
});

Object.defineProperties(raisedAmount, {
  _dollars: {
    enumerable: false,
    writable: true
  },
  _cents: {
    enumerable: false,
    writable: true
  }
});

raisedAmount._dollars = 600;
raisedAmount._cents = 0;
```

We create another object, but we can reuse the existing functions. Let's make sure:

```
rentAmount.dollars()  
//=> 420  
  
raisedAmount.dollars()  
//=> 600
```

What does this accomplish? Well, it “hides” the raw properties by making them enumerable, then provides access (if any) to other objects through functions that can be shared amongst multiple objects.

As we saw earlier, this allows us to choose whether to expose setters as well as getters, it allows us to validate inputs, or even to have non-enumerable properties that are used by an object’s functions to hold state.

The naming convention is useful, and of course you can use whatever convention you like. My personal preference for a very long time was to preface private names with `my`, such as `myDollars`. Underscores work just as well, and that’s what we’ll use in this book.

summary

JavaScript does not have a way to enforce restrictions on accessing an object’s properties: Any code that knows the name of a property can access the value, setter, or getter that has been defined for the object.

Private data can be faked with closures, at a cost in memory.

JavaScript does allow properties to be non-enumerable. In combination with a naming convention and/or setters and getters, a reasonable compromise can be struck between fully private instance variables and completely open access.

Object-1s and Object-2s

In the discussion of hiding properties, we saw the example of a dictionary object. Here it is with its *domain properties*, the properties that correspond to the state of the object:

```
var dictionary = {
  abstraction: "an abstract or general idea or term",
  encapsulate: "to place in or as if in a capsule",
  object: "anything that is visible or tangible and is relatively stable in form"
};
```

By default, JavaScript permits us to add “behaviour” to the dictionary by binding functions to properties. We’ve already seen a better solution, but let’s back up for a moment and write:

```
dictionary.describe = function () {
  return map(['abstraction', 'encapsulate', 'object'], function (key) {
    return key + ': "' + dictionary[key] + '"';
  }).join('; ');
};

dictionary.describe()
//=>
'abstraction: "an abstract or general idea or term"; encapsulate: "to place i\
n or as if in a capsule";
object: "anything that is visible or tangible and is relatively stable in for\
m"'
```

What happens if we get the keys of our object? By now, you know the answer immediately:

```
Object.keys(dictionary)
//=>
[ 'abstraction',
  'encapsulate',
  'object',
  'describe' ]
```

The `describe` property is exactly the same as the `abstraction`, `encapsulate`, and `object` properties. This is not surprising once you’ve grasped the fact that JavaScript is sometimes described as a “Lisp-1.”

What what?

lisp-1s and lisp-2s

One of the big schisms in the history of the Lisp programming languages is over namespaces. In one branch of the tree, functions live in the same namespace as every other kind of value. So a name like `setvar` can be bound to any kind of value: A symbol, a string, a list, a function, whatever. Lisps with this namespace system are called “Lisp-1s” because they have one namespace for everything.¹⁸

So in a Lisp-1, (`map someList myFun`) calls the function bound to the name `map`, passing along the values bound to the symbols `someList` and `myFun`. `myFun` can (and should) be a function, and that’s fine.

Other Lisps use a different system. Functions live in their own namespace. So `setvar` wouldn’t be bound to a function, but it could be a symbol, list, or anything else. If you want a function named “`setvar`,” you need special syntax to reach into the function namespace, like `#' setvar`.¹⁹

In a Lisp-2, (`map someList myFun`) calls the function bound to the name `map`, passing along the values bound to the symbols `someList` and `myFun`. But it’s not going to work, because it’s going to look up the non-function value bound to the name `myFun`. To make it work properly, we need something like (`map someList #'myFun`), indicating that we want to go into the function namespace to look up `myFun`.

javascript is a javascript-1

In JavaScript, all values live in the same namespace. Anywhere you write a variable name like `foo`, it could be a function or it could be an “ordinary” value like an object, string, or number. When we write something like:

```
map(someLisp, myFun)
```

All three names (`map`, `someLisp`, and `myFun`) are looked up in the same namespace and can contain functions or ordinary values. This is simpler and cleaner than having special rules for how to look functions up.

javascript is also an object-1

As we’ve seen repeatedly, JavaScript objects have properties, and those properties can be either functions or ordinary values. If we write:

¹⁸Some people argue that Lisp-1 and Lisp-2 are examples of “opaque jargon” and are a communication anti-pattern.

¹⁹Why are there two different ways to handle namespaces in the Lisp family of languages? Some theorize that it goes back to some early implementation detail, perhaps it was efficient to put all the functions in one big data structure and put everything else in another. or perhaps it saved checking that something really is a function before invoking it, a rudimentary form of static type-checking.

```
dictionary.length
```

We might be accessing a function, we might be accessing a number. The only way to know is to try it:

```
var dictionary = {
  abstraction: "an abstract or general idea or term",
  encapsulate: "to place in or as if in a capsule",
  object: "anything that is visible or tangible and is relatively stable in form"
};

Object.defineProperty(dictionary, 'length', {
  enumerable: false,
  writable: false,
  value: function () {
    return Object.keys(this).length;
  }
});

dictionary.length
//=> [Function]
```

Thus, by default, JavaScript's properties are a single namespace containing both functions and ordinary values. The functions we assign as behaviours of the object live alongside the values that belong to the domain.

Not all “OO” languages are “Object-1s.” Ruby, for example, is an “Object-2.” In Ruby, object methods live in a complete different namespace from their instance variables, and both of them live in a complete different namespace from the contents of containers like Hashes.

For example:

```
dictionary = Object.new

dictionary.instance_variable_set(:@abstraction, "an abstract or general idea or t\
erm")

def dictionary.abstraction
  "the act of considering something as a general quality or characteristic, " +
  "apart from concrete realities, specific objects, or actual instances."
end
```

Its methods and instance variables are assigned as if they're separate things. Let's access them from outside the object:

```
dictionary.instance_variable_get(:@abstraction)
#=> "an abstract or general idea or term"

dictionary.abstraction
#=> "the act of considering something as a general quality or characteristic,
apart from concrete realities, specific objects, or actual instances.
```

And from within its own methods?

```
def dictionary.tryThis
  puts @abstraction, nil, abstraction
end

dictionary.tryThis
#=>
an abstract or general idea or term

the act of considering something as a general quality or characteristic,
apart from concrete realities, specific objects, or actual instances.
```

In Ruby, instance variables live in their own namespace separately from methods, you have to use a sigil, @ to access them. Ruby is an Object-2.

writing javascript in object-2 style

It's a huge benefit that JavaScript is a “Lisp-1” in the sense that there is one namespace for all variables. But it can be a benefit to write JavaScript in an “Object-2” style, separating our methods from our domain properties.

One of the practices we saw earlier was to hide properties by making them non-enumerable. This is often useful for methods:

```
var dictionary = {
  abstraction: "an abstract or general idea or term",
  encapsulate: "to place in or as if in a capsule",
  object: "anything that is visible or tangible and is relatively stable in form"
};

Object.defineProperty(dictionary, 'length', {
  enumerable: false,
  writable: false,
  value: function () {
```

```

    return Object.keys(this).length;
}
});
};

Object.keys(dictionary).indexOf('value') >= 0
//=> false

```

As we see, `Object.keys` gives us the names of the enumerable properties, the ones we're using for domain state. What about the non-enumerable properties? We have a partial answer with `Object.getOwnPropertyNames`:

```

Object.getOwnPropertyNames(dictionary)
//=>
[ 'abstraction',
  'encapsulate',
  'object',
  'length' ]

```

Given this, we can construct:

```

function methods (object) {
  var domainProperties = Object.keys(object);

  return Object.getOwnPropertyNames(object).filter( function (name) {
    return typeof(object[name]) === 'function' && domainProperties.indexOf(name) \
    === -1;
  })
}

methods(dictionary)
//=> ['length']

```

We will need to be strict about making all of your methods non-enumerable to use this function. We'll also have to rethink our approach to listing methods when we start working with metaobjects, the topic of the next chapter.

To Do

object composition and delegation

state machines and strategies

nouns, verbs and commands

immediate, forward, and late-binding

Methods



20

introductory remarks coming soon

²⁰Vacuum Pots (c) 2012 Olin Viydo, [some rights reserved](#)

What is a Method?

As an abstraction, an object is an independent entity that maintains internal state and that responds to messages by reporting its internal state and/or making changes to its internal state. In the course of handling a message, an object may send messages to other objects and receive replies from them.

A “method” is an another idea that is related to, but not the same as, handling a message. A method is a function that encapsulates an object’s behaviour. Methods are invoked by a calling entity much as a function is invoked by some code.

The distinction may seem subtle, but the easiest way to grasp the distinction is to focus on the word “message.” A message is an entity of its own. You can store and forward a message. You can modify it. You can copy it. You can dispatch it to multiple objects. You can put it on a “blackboard” and allow objects to decide for themselves whether they want to respond to it.

Methods, on the other hand, operate “closer to the metal.” They look and behave like function calls. In JavaScript, methods *are* functions. To be a method, a function must be the property of an object. We’ve seen methods earlier, here’s a naïve example:

```
var dictionary = {
    abstraction: "an abstract or general idea or term",
    encapsulate: "to place in or as if in a capsule",
    object: "anything that is visible or tangible and is relatively stable in form",
    descriptor: function () {
        return map(['abstraction', 'encapsulate', 'object'], function (key) {
            return key + ': "' + dictionary[key] + '"';
        }).join('; ');
    }
};

dictionary.descriptor()
//=>
'abstraction: "an abstract or general idea or term"; encapsulate: "to place i\
n or as if in a capsule";
object: "anything that is visible or tangible and is relatively stable in for\
m"'
```

In this example, `descriptor` is a method. As we saw earlier, this code has many problems, but let’s hand-wave them for a moment. Let’s be clear about our terminology. This `dictionary` object has a method called `descriptor`. The function associated with `descriptor` is called the *method handler*.

When we write `dictionary.descriptor()`, we’re *invoking or calling the descriptor method*. The object is then *handling the method invocation* by evaluating the function.

In describing objects, we refer to objects as encapsulating their internal state. The ideal is that objects **never** directly access or manipulate each other's state. Instead, objects interact with each other solely through methods.

There are many things that methods can do. Two of the most obvious are to *query* an object's internal state and to *update* its state. Methods that have no purpose other than to report internal state are called queries, while methods that have no purpose other than to update an object's internal state are called updates.

The Letter and the Spirit of the Law

The ‘law’ that objects must only interact with each other through methods is generally accepted as an ideal, even though languages like JavaScript and Java do not enforce it. That being said, there are (roughly) two philosophies about the design of objects and their methods.

- *Literalists* believe that the important thing is the means of interaction be methods. Literalists are noted for using a profusion of getters and setters, which leads to code that is semantically identical to code where objects interact with each other’s internal state, but every interaction is performed indirectly through a query or update.
- *Semanticists* believe that the important thing is that objects provide abstractions over their internal state. They avoid getters and setters, preferring to provide methods that are a level of abstraction above their internal representations.

By way of example, let’s imagine that we have a person object. Our first cut at it involves storing a name. Here’s a first cut at a literalist implementation:

```
var person = Object.create(null, {
  _firstName: {
    enumerable: false,
    writable: true
  },
  _lastName: {
    enumerable: false,
    writable: true
  },
  getFirstName: {
    enumerable: false,
    writable: true,
    value: function () {
      return _firstName;
    }
  },
  setFirstName: {
    enumerable: false,
    writable: true,
    value: function (str) {
      return _firstName = str;
    }
  },
  getLastname: {
```

```

enumerable: false,
writable: true,
value: function () {
  return _lastName;
},
setLastName: {
  enumerable: false,
  writable: true,
  value: function (str) {
    return _lastName = str;
  }
}
);

```

This is largely pointless as it stands. Other objects now write `person.setFirstName('Bilbo')` instead of `person.firstName = 'Bilbo'`, but nothing of importance has been improved. The trouble with this approach as it stands is that it is a holdover from earlier times. Much of the trouble stems from design decisions made in languages like C++ and Java to preserve C-like semantics.

In those languages, once you have some code written as `person.firstName = 'Bilbo'`, you are forever stuck with `person` exposing a property to direct access. Without changing the semantics, you may later want to do something like make `person observable21`, that is, we add code such that other objects can be notified when the `person` object's name is updated.

If `firstName` is a property being directly updated by other entities, we have no way to insert any code to handle the updating. The same argument goes for something like validating the name. Although validating names is a morass in the real world, we might have simple ideas such as that the first name will either have at least one character or be `null`, but never an empty string. If other entities directly update the property, we can't enforce this within our object.

In days of old, programmers would have needed to go through the code base changing `person.firstName = 'Bilbo'` into `person.setName('Bilbo')` (or even worse, adding all the observable code and validation code to other entities).

Thus, the literalist tradition grew of defining getters and setters as methods even if no additional functionality was needed immediately. With the code above, it is straightforward to introduce validation and observability:²²

²¹https://en.wikipedia.org/wiki/Observer_pattern

²²Later on, we'll see how to use `method combinators` to do this more elegantly.

```
var person = Object.create(null, {
  // ...
  setFirstName: {
    enumerable: false,
    writable: true,
    value: function (str) {
      // insert validation and observable boilerplate here
      return _firstName = str;
    }
  },
  setLastName: {
    enumerable: false,
    writable: true,
    value: function (str) {
      // insert validation and observable boilerplate here
      return _lastName = str;
    }
  }
});
```

That seems very nice, but balanced against this is that contemporary implementations of JavaScript allow you to write getters and setters for properties that mediate access even when other entities are using property access syntax like `person.lastName = 'Baggins'`:

```
var person = Object.create(null, {
  _firstName: {
    enumerable: false,
    writable: true
  },
  firstName: {
    get: function () {
      return _firstName;
    },
    set: function (str) {
      // insert validation and observable boilerplate here
      return _firstName = str;
    }
  },
  _lastName: {
    enumerable: false,
    writable: true
  },
  lastName: {
    get: function () {
      return _lastName;
    },
    set: function (str) {
      // insert validation and observable boilerplate here
      return _lastName = str;
    }
  }
});
```

```

lastName: {
  get: function () {
    return _lastName;
  },
  set: function (str) {
    // insert validation and observable boilerplate here
    return _lastName = str;
  }
}
});

```

The preponderance of evidence suggests that if you are a literalist, you are better off not bothering with making getters and setters for everything in JavaScript, as you can add them later if need be.

the semantic interpretation of object methods²³

What about the semantic approach?

With the literalist, properties like `firstName` are decoupled from methods like `setFirstName` so that the implementation of the properties can be managed by the object. Other objects calling `person.setFirstName('Frodo')` are insulated from details such as whether other objects are to be notified when `person` is changed.

But while the implementation is hidden, there is no abstraction involved. The level of abstraction of the properties is identical to the level of abstraction of the methods.

The semanticist takes this one step further. To the semanticist, objects insulate other entities from implementation details like observables and validation, but objects also provide an abstraction to other entities.

In our `person` example, first and last name is a very low-level concern, the kind of thing you think about when you're putting things in a database and worrying about searching and sorting performance. But what would be a higher-level abstraction?

Just a name.

You ask someone their name, they tell you. You ask for a name, you get it. An object that takes and accepts names hides from us all the icky questions like:

1. How do we handle people who only have one name? (it's not just celebrities)
2. Where do we store the extra middle names like Tracy Christopher Anthony Lee?
3. How do we handle formal Spanish names like [Gabriel José de la Concordia García Márquez](#)²⁴?

²³With the greatest respect to [Chongo](#), author of “The Homeless Interpretation of Quantum Mechanics.”

²⁴https://en.wikipedia.org/wiki/Gabriel_Garc%C3%ADa_M%C3%A1rquez

4. What do we do with [maiden names](#)²⁵ like Arlene Gwendolyn Lee née Barzey or Leocadia Blanco Álvarez de Pérez?

If we expose the low-level fields to other code, we demand that they know all about our object's internals and do the parsing where required. It may be simpler and easier to simply expose:

```
var person = Object.create(null, {
  _givenNames: {
    enumerable: false,
    writable: true,
    value: []
  },
  _maternalSurname: {
    enumerable: false,
    writable: true
  },
  _paternalSurname: {
    enumerable: false,
    writable: true
  },
  _premaritalName: {
    enumerable: false,
    writable: true
  },
  name: {
    get: function () {
      // ...
    },
    set: function (str) {
      // ...
    }
  }
});
```

The person object can then do the “icky” work itself. This centralizes responsibility for names.

Now, honestly, people have been handling names in a very US-centric way for a very long time, and few will put up a fuss if you make objects with highly literal name implementations. But the example illustrates the divide between a *literal design* where other objects operate at the same level of abstraction as the object's internals, and a *semantic design*, one that operates at a higher level of abstraction and is responsible for translating methods into queries and updates on the implementation.

²⁵https://en.wikipedia.org/wiki/Married_and_maiden_names

Composite Methods

One of the primary activities in programming is to *factor* programs or algorithms, to break them into smaller parts that can be reused or recombined in different ways.

Common industry practice is to use the words “decompose” and “factor” interchangeably to refer to any breaking of code into smaller parts. Nevertheless, we will defy industry practice and use the word “decompose” to refer to breaking code into smaller parts whether those parts are to be recombined or reused or not, and use the word “factor” to refer to the stricter case of decomposition where the intention is to recombine or reuse the parts in different ways.

Both methods and objects can and should be factored into reusable components that have a single, well-defined responsibility²⁶²⁷

The simplest way to decompose a method is to “extract” one or more helper methods. For example:

```
var person = Object.create(null, {
    // ...
    setFirstName: {
        enumerable: false,
        writable: true,
        value: function (str) {
            if (typeof(str) === 'string' && str !== '') {
                return this._firstName = str;
            }
        }
    },
    setLastName: {
        enumerable: false,
        writable: true,
        value: function (str) {
            if (typeof(str) === 'string' && str !== '') {
                return this._lastName = str;
            }
        }
    }
});
```

²⁶https://en.wikipedia.org/wiki/Single_responsibility_principle

²⁷Robert Martin's rule of thumb for determining whether a method has a single responsibility is to ask when and why it would ever change. If there is just one reason why you are likely to change a method, it has a single responsibility. If there is more than one reason why it might change, it should be decomposed into separate entities that each have a single responsibility.

The methods `setFirstName` and `setLastName` both have a “guard clause” that will not update the object’s hidden state unless the method is passed a non-empty string. The logic can be extracted into its own “helper method.”

```
var person = Object.create(null, {
    // ...
    isValidName: {
        enumerable: false,
        writable: false,
        value: function (str) {
            return (typeof(str) === 'string' && str != '');
        }
    },
    setFirstName: {
        enumerable: false,
        writable: true,
        value: function (str) {
            if (this.isValidName(str)) {
                return this._firstName = str;
            }
        }
    },
    setLastName: {
        enumerable: false,
        writable: true,
        value: function (str) {
            if (this.isValidName(str)) {
                return this._lastName = str;
            }
        }
    }
});
```

The methods `setFirstName` and `setLastName` now call the helper method `isValidName`. The usual motivation for this is known as [DRY²⁸](#) or “Don’t Repeat Yourself.” The DRY principle is stated as “Every piece of knowledge must have a single, unambiguous, authoritative representation within a system.”

In this case, presumably there is one idea, “person names must be non-empty strings,” and placing the implementation for this in the `isValidString` helper method ensures that now there is just the

²⁸https://en.wikipedia.org/wiki/Don%27t_repeat_yourself

one authoritative source for the logic, instead of one in each name setter method.

Decomposing a method needn't always be for the purpose of DRYing up the logic. Sometimes, a method breaks down logically into a hierarchy of steps. For example:

```
var person = Object.create(null, {  
  // ...  
  
  doSomethingComplicated: {  
    enumerable: false,  
    writable: true,  
    value: function () {  
      this.setUp();  
      this.doTheWork();  
      this.breakdown();  
      this.cleanUp();  
    }  
  },  
  setUp: // ...  
  doTheWork: // ...  
  breakdown: // ...  
  cleanUp: // ...  
});
```

This is as true of methods as it is of functions in general. However, objects have some extra considerations. The most conspicuous is that an object is its own namespace. When you break a method down into helpers, you are adding items to the namespace, making the object as a whole more difficult to understand. What methods call `setUp`? Can `breakdown` be called independently of `cleanUp`? Everything is thrown into an object higgledy-piggledy.

decluttering with closures

JavaScript provides us with tools for reducing object clutter. The first is the [Immediately Invoked Function Expression²⁹](#) (“IIFE”). If our four helpers exist only to decompose `doSomethingComplicated`, we can write:

²⁹https://en.wikipedia.org/wiki/Immediately-invoked_function_expression

```
var person = Object.create(null, {  
  
    // ...  
  
    doSomethingComplicated: {  
        enumerable: false,  
        writable: true,  
        value: (function () {  
            return function () {  
                setUp.call(this);  
                doTheWork.call(this);  
                breakdown.call(this);  
                cleanUp.call(this);  
            };  
            function setUp () {  
                // ...  
            }  
            function doTheWork () {  
                // ...  
            }  
            function breakdown () {  
                // ...  
            }  
            function cleanUp () {  
                // ...  
            }  
        })()  
    },  
});
```

Now our four helpers exist only within the closure created by the IIFE, and thus it is impossible for any other method to call them. You could even create a `setUp` helper with a similar name for another function without clashing with this one. Note that we're not invoking these functions with `this.`, because they aren't methods any more. And to preserve the local object's context, we're calling them with `.call(this)`.

decluttering with method objects

In JavaScript, methods are represented by functions. And in JavaScript, *functions are objects*. Functions have properties, and the properties behave just like objects we create with `{}` or `Object.create`:

```
var K = function (x) {
  return function (y) {
    return x;
  };
};

Object.defineProperty(K, 'longName', {
  enumerable: true,
  writable: false,
  value: 'The K Combinator'
});

K.longName
//=> 'The K Combinator'

Object.keys(K)
//=> [ 'longName' ]
```

We can take advantage of this by using a function as a container for its own helper functions. There are several easy patterns for this. Of course, you could write it all out by hand:

```
function doSomethingComplicated () {
  doSomethingComplicated.setUp.call(this);
  doSomethingComplicated.doTheWork.call(this);
  doSomethingComplicated.breakdown.call(this);
  doSomethingComplicated.cleanUp.call(this);
}

doSomethingComplicated.setUp = function () {
  // ...
}

doSomethingComplicated.doTheWork = function () {
  // ...
}

doSomethingComplicated.breakdown = function () {
  // ...
}

doSomethingComplicated.cleanUp = function () {
  // ...
```

```
}
```

```
var person = Object.create(null, {
```

```
// ...
```

```
doSomethingComplicated: {
```

```
enumerable: false,
```

```
writable: true,
```

```
value: doSomethingComplicated
```

```
}
```

```
});
```

If we'd like to make it neat and tidy inline, `tap` is handy:

```
var person = Object.create(null, {
```

```
// ...
```

```
doSomethingComplicated: {
```

```
enumerable: false,
```

```
writable: true,
```

```
value: tap(
```

```
function doSomethingComplicated () {
```

```
doSomethingComplicated.setUp.call(this);
```

```
doSomethingComplicated.doTheWork.call(this);
```

```
doSomethingComplicated.breakdown.call(this);
```

```
doSomethingComplicated.cleanUp.call(this);
```

```
}, function (its) {
```

```
its.setUp = function () {
```

```
// ...
```

```
}
```

```
its.doTheWork = function () {
```

```
// ...
```

```
}
```

```
its.breakdown = function () {
```

```
// ...
```

```
}
```

```
its.cleanUp = function () {
```

```
// ...
}
})
}
});
```

In terms of code, this is no simpler than the IIFE solution. However, placing the helper methods inside the function itself does make them available for use or modification by other methods. For example, you can now use a method decorator on any of the helpers:

```
var logsTheReciver = after( function (value) {
  console.log(this);
  return value;
});
```

```
person.doSomethingComplicated.doTheWork = logsTheReciver(person.doSomethingCompli\
cated.doTheWork);
```

This would not have been possible if `doTheWork` was hidden inside a closure.

summary

Like “ordinary” functions, methods can benefit from being decomposed or factored into smaller functions. Two of the motivations for doing so are to DRY up the code and to break a method into more easily understood and obvious parts. The parts can be represented as helper methods, functions hidden in a closure, or properties of the method itself.

Meta-Methods

function helpers

If functions are objects, and functions can have properties, then functions can have methods. We can give functions our own methods by assigning functions to their properties. We saw this previously when we decomposed an object's method into helper methods. Here's the same applied to a function:

```
function factorial (n) {
  return factorial.helper(n, 1);
}

factorial.helper = function helper (n, accumulator) {
  if (n === 0) {
    return accumulator;
  }
  else return helper(n - 1, n * accumulator);
}
```

Functions can have all sorts of properties. One of the more intriguing possibility is to maintain an array of functions:

```
function sequencer (arg) {
  var that = this;

  return sequencer._functions.reduce( function (acc, fn) {
    return fn.call(that, acc);
  }, arg);
}

Object.defineProperties(sequencer, {
  _functions: {
    enumerable: false,
    writable: false,
    value: []
  }
});
```

sequencer is an object-oriented way to implement the pipeline function from function-oriented libraries like allong.es³⁰. Instead of writing something like:

³⁰<http://allong.es>

```
function square (n) { return n * n; }
function increment (n) { return n + 1; }

pipeline(square, increment)(6)
//=> 37
```

We can write:

```
sequencer._functions.push(square);
sequencer._functions.push(increment);

sequencer(6)
//=> 37
```

The functions contained within the `_functions` array are helper methods. They work they same way as is we'd written something like:

```
function squarePlusOne (arg) {
  return squarePlusOne.increment(
    squarePlusOne.square(arg)
  );
}
squarePlusOne.increment = increment;
squarePlusOne.square = square;

squarePlusOne(6)
//=> 37
```

The only difference is that they're dynamically looked up helper methods instead of statically wired in place by the body of the function. But they're still helper methods.

function methods

The obvious problem with our approach is that we aren't using our method as an object in the ideal sense. Why should other entities manipulate its internal state? If this were any other kind of object, we'd expose methods handle messages from other entities.

Let's try it:

```
Object.defineProperties(sequencer, {
  push: {
    enumerable: false,
    writable: false,
    value: function (fn) {
      return this._functions.push(fn);
    }
  }
});
```

Now we can manipulate our sequencer without touching its privates:

```
sequencer.push(square);
sequencer.push(increment);

sequencer(6)
//=> 37
```

Is it a big deal to eliminate the `_functions` reference? Yes!

1. This hides the implementation: Do we have an array of functions? Or maybe we are composing the functions with a combinator? Who knows?
2. This prevents us manipulating internal state in unauthorized ways, such as calling `sequencer._functions.reverse()`

`sequencer.push` is a proper method, a function that handles messages from other entities and in the course of handling the message, queries and/or updates the function's internal state.

If we're going to treat functions like objects, we ought to give them methods.

aspect-oriented programming and meta-methods

When an object has a function as one of its properties, that's a method. And we just established that functions can have methods. So... Can a method have methods?

Most assuredly.

Here's an example that implements a simplified form of [Aspect-Oriented Programming](#)³¹

Consider a `businessObject` and a `businessObjectCollection`. Never mind what they are, that isn't important. We start with the idea that a `businessObject` can be `valid` or `invalid`, and there's a method for querying this:

³¹https://en.wikipedia.org/wiki/Aspect-oriented_programming

```
var businessObject = Object.create(null, {
  // ...
  isValid: {
    enumerable: false,
    value: function () {
      // ...
    }
  }
});
```

Obviously, the `businessCollection` has methods for adding business objects and for finding business objects:

```
var businessCollection = Object.create(null, {
  // ...
  add: {
    enumerable: false,
    value: function (bobj) {
      // ...
    }
  },
  find: {
    enumerable: false,
    value: function (fn) {
      // ...
    }
  }
});
```

Our `businessCollection` is just a collection, it doesn't actually do anything to the business objects it holds.

One day, we decide that it is an error if an invalid business object is placed in a business collection, and also an error if an invalid business object is returned when you call `businessCollection.find`. To "fail fast" in these situations, we decide that an exception should be thrown when this happens.

Should we add some checking code to `businessCollection.add` and `businessCollection.find`? Yes, but we shouldn't modify the methods themselves. Since `businessCollection`'s single responsibility is storing objects, business rules about the state of the objects being stored should be placed in some other code.

What we'd like to do is "advise" the `add` method with code that is to be run before it runs, and advise the `find` method with code that runs after it runs. If our methods had methods, we could write:

```
businessCollection.add.beforeAdvice(function (bobjProvided) {
  if (!bobjProvided.isValid())
    throw 'bad object provided to add';
});

businessCollection.find.afterAdvice(function (bobjReturned) {
  if (bobjReturned && !bobjReturned.isValid())
    throw 'bad object returned from find';
});
```

As you can see, we've invented a little protocol. `.beforeAdvice` adds a function "before" a method, and `.afterAdvice` adds a function "after" a method. We'll need a function to make method objects out of the desired method functions:

```
function advisable (methodBody) {

  function theMethod () {
    var args = [].slice.call(arguments);

    theMethod.befores.forEach( function (advice) {
      advice.apply(this, args);
    }, this);

    var returnValue = theMethod.body.apply(this, arguments);

    theMethod.afters.forEach( function (advice) {
      advice.call(this, returnValue);
    }, this);

    return returnValue;
  }

  Object.defineProperties(theMethod, {
    befores: {
      enumerable: true,
      writable: false,
      value: []
    },
    body: {
      enumerable: true,
      writable: false,
      value: body
    }
  });
}
```

```
},
afters: {
  enumerable: true,
  writable: false,
  value: []
},
beforeAdvice: {
  enumerable: false,
  writable: false,
  value: function (fn) {
    this.befores.unshift(fn);
    return this;
  }
},
afterAdvice: {
  enumerable: false,
  writable: false,
  value: function (fn) {
    this.afters.push(fn);
    return this;
  }
}
});

return theMethod;
}
```

Let's rewrite our `businessCollection` to use our `advisable` function:

```
var businessCollection = Object.create(null, {
  // ...
  add: {
    enumerable: false,
    value: advisable(function (bobj) {
      // ...
    })
  },
  find: {
    enumerable: false,
    value: advisable(function (fn) {
      // ...
    })
  }
});
```

```
    }  
});
```

And now, exactly as above, we can write `businessCollection.add.beforeAdvice` and `businessCollection.find.afterAdvice`, separating the responsibility for error checking from the responsibility for managing a collection of business objects.

`beforeAdvice` and `afterAdvice` are methods of methods, or more simply, *meta-methods*.