

The Objective-C Programming Language

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Introduction

The Objective-C language is a simple computer language designed to enable sophisticated object-oriented programming. Objective-C is defined as a small but powerful set of extensions to the standard ANSI C language. Its additions to C are mostly based on Smalltalk, one of the first object-oriented programming languages. Objective-C is designed to give C full object-oriented programming capabilities, and to do so in a simple and straightforward way.

Most object-oriented development environments consist of several parts:

- An object-oriented programming language
- A library of objects
- A suite of development tools
- A runtime environment

This document is about the first component of the development environment—the programming language. This document also provides a foundation for learning about the second component, the Objective-C application frameworks—collectively known as **Cocoa**. The runtime environment is described in a separate document, *Objective-C Runtime Programming Guide*.

Who Should Read This Document

The document is intended for readers who might be interested in:

- Programming in Objective-C
- Finding out about the basis for the Cocoa application frameworks

This document both introduces the object-oriented model that Objective-C is based upon and fully documents the language. It concentrates on the Objective-C extensions to C, not on the C language itself.

Because this isn't a document about C, it assumes some prior acquaintance with that language. Object-oriented programming in Objective-C is, however, sufficiently different from **procedural programming** in ANSI C that you won't be hampered if you're not an experienced C programmer.

Organization of This Document

The following chapters cover all the features Objective-C adds to standard C.

- “Objects, Classes, and Messaging” (page 10)
- “Defining a Class” (page 33)
- “Protocols” (page 50)
- “Declared Properties” (page 62)
- “Categories and Extensions” (page 73)
- “Associative References” (page 76)
- “Fast Enumeration” (page 80)
- “Enabling Static Behavior” (page 83)
- “Selectors” (page 88)
- “Exception Handling” (page 93)
- “Threading” (page 96)

A glossary at the end of this document provides definitions of terms specific to Objective-C and object-oriented programming.

Conventions

This document makes special use of computer voice and italic fonts. Computer voice denotes words or characters that are to be taken literally (typed as they appear). Italic denotes words that represent something else or can be varied. For example, the syntax:

```
@interfaceClassName ( CategoryName )
```

means that `@interface` and the two parentheses are required, but that you can choose the class name and category name.

Where example code is shown, ellipsis points indicates the parts, often substantial parts, that have been omitted:

```
- (void)encodeWithCoder:(NSCoder *)coder  
{  
    [super encodeWithCoder:coder];  
    ...  
}
```



```
}
```

See Also

If you have never used object-oriented programming to create applications, you should read *Object-Oriented Programming with Objective-C*. You should also consider reading it if you have used other object-oriented development environments such as C++ and Java because they have many expectations and conventions different from those of Objective-C. *Object-Oriented Programming with Objective-C* is designed to help you become familiar with object-oriented development from the perspective of an Objective-C developer. It spells out some of the implications of object-oriented design and gives you a flavor of what writing an object-oriented program is really like.

The Runtime System

Objective-C Runtime Programming Guide describes aspects of the Objective-C runtime and how you can use it.

Objective-C Runtime Reference describes the data structures and functions of the Objective-C runtime support library. Your programs can use these interfaces to interact with the Objective-C runtime system. For example, you can add classes or methods, or obtain a list of all class definitions for loaded classes.

Memory Management

Objective-C supports three mechanisms for memory management: automatic garbage collection and reference counting:

- **Automatic Reference Counting** (ARC), where the compiler reasons about the lifetimes of objects.
- **Manual Reference Counting** (MRC, sometimes referred to as MRR for “manual retain/release”), where you are ultimately responsible for determining the lifetime of objects.

Manual reference counting is described in *Advanced Memory Management Programming Guide*.

- **Garbage collection**, where you pass responsibility for determining the lifetime of objects to an automatic “collector.”

Garbage collection is described in *Garbage Collection Programming Guide*. (Not available for iOS—you cannot access this document through the iOS Dev Center.)

Objects, Classes, and Messaging

This chapter describes the fundamentals of objects, classes, and messaging as used and implemented by the Objective-C language. It also introduces the Objective-C runtime.

The Runtime System

The Objective-C language defers as many decisions as it can from **compile time** and **link time** to **runtime**. Whenever possible, it dynamically performs operations such as creating objects and determining what method to invoke. Therefore, the language requires not just a compiler, but also a runtime system to execute the compiled code. The runtime system acts as a kind of operating system for the Objective-C language; it's what makes the language work. Typically, however, you don't need to interact with the runtime directly. To understand more about the functionality it offers, though, see *Objective-C Runtime Programming Guide*.

Objects

As the name implies, object-oriented programs are built around **objects**. An object associates data with the particular operations that can use or affect that data. Objective-C provides a data type to identify an object variable without specifying a particular class of the object.

Object Basics

An object associates data with the particular operations that can use or affect that data. In Objective-C, these operations are known as the object's **methods**; the data they affect are its **instance variables** (in other environments they may be referred to as *ivars* or *member variables*). In essence, an object bundles a data structure (instance variables) and a group of procedures (methods) into a self-contained programming unit.

In Objective-C, an object's instance variables are internal to the object; generally, you get access to an object's state only through the object's methods (you can specify whether subclasses or other objects can access instance variables directly by using scope directives, see [“The Scope of Instance Variables”](#) (page 40)). For others to find out something about an object, there has to be a method to supply the information. For example, a rectangle would have methods that reveal its size and position.

Moreover, an object sees only the methods that were designed for it; it can't mistakenly perform methods intended for other types of objects. Just as a C function protects its local variables, hiding them from the rest of the program, an object hides both its instance variables and its method implementations.

id

In Objective-C, object identifiers are of a distinct data type: `id`. This type is the general type for any kind of object regardless of class and can be used for instances of a class and for class objects themselves.

```
id anObject;
```

For the object-oriented constructs of Objective-C, such as method return values, `id` replaces `int` as the default data type. (For strictly C constructs, such as function return values, `int` remains the default type.)

The keyword `nil` is defined as a null object, an `id` with a value of 0. `id`, `nil`, and the other basic types of Objective-C are defined in the header file `objc/objc.h`.

`id` is defined as pointer to an object data structure:

```
typedef struct objc_object {  
    Class isa;  
} *id;
```

Every object thus has an `isa` variable that tells it of what class it is an instance. Since the `Class` type is itself defined as a pointer:

```
typedef struct objc_class *Class;
```

the `isa` variable is frequently referred to as the “`isa` pointer.”

Dynamic Typing

The `id` type is completely nonrestrictive. By itself, it yields no information about an object, except that it is an object. At some point, a program typically needs to find more specific information about the objects it contains. Since the `id` type designator can't supply this specific information to the compiler, each object has to be able to supply it at runtime.

The `isa` instance variable identifies the object's **class**—what kind of object it is. Objects with the same behavior (methods) and the same kinds of data (instance variables) are members of the same class.

Objects are thus **dynamically typed** at runtime. Whenever it needs to, the runtime system can find the exact class that an object belongs to, just by asking the object. (To learn more about the runtime, see *Objective-C Runtime Programming Guide*.) Dynamic typing in Objective-C serves as the foundation for dynamic binding, discussed later.

The `isa` variable also enables objects to perform introspection—to find out about themselves (or other objects). The compiler records information about class definitions in data structures for the runtime system to use. The functions of the runtime system use `isa` to find this information at runtime. Using the runtime system, you can, for example, determine whether an object implements a particular method or discover the name of its superclass.

Object classes are discussed in more detail under [“Classes”](#) (page 19).

It’s also possible to give the compiler information about the class of an object by statically typing it in source code using the class name. Classes are particular kinds of objects, and the class name can serve as a type name. See [“Class Types”](#) (page 23) and [“Enabling Static Behavior”](#) (page 83).

Memory Management

In any program, it is important to ensure that objects are deallocated when they are no longer needed—otherwise your application’s memory footprint becomes larger than necessary. It is also important to ensure that you do not deallocate objects while they’re still being used.

Objective-C offers three mechanisms for memory management that allow you to meet these goals:

- **Automatic Reference Counting** (ARC), where the compiler reasons about the lifetimes of objects.
- **Manual Reference Counting** (MRC, sometimes referred to as MRR for “manual retain/release”), where you are ultimately responsible for determining the lifetime of objects.

Manual reference counting is described in *Advanced Memory Management Programming Guide*.

- **Garbage collection**, where you pass responsibility for determining the lifetime of objects to an automatic “collector.”

Garbage collection is described in *Garbage Collection Programming Guide*. (Not available for iOS—you cannot access this document through the iOS Dev Center.)

Object Messaging

This section explains the syntax of sending messages, including how you can nest message expressions. It also discusses the scope or “visibility” of an object’s instance variables, and the concepts of polymorphism and dynamic binding.

Message Syntax

To get an object to do something, you send it a **message** telling it to apply a method. In Objective-C, **message expressions** are enclosed in brackets:

```
[receiver message]
```

The **receiver** is an object, and the message tells it what to do. In source code, the message is simply the name of a method and any parameters that are passed to it. When a message is sent, the runtime system selects the appropriate method from the receiver's repertoire and invokes it.

For example, this message tells the `myRectangle` object to perform its `display` method, which causes the rectangle to display itself:

```
[myRectangle display];
```

The message is followed by a `“;”` as is normal for any statement in C.

Because the method name in a message serves to “select” a method implementation, method names in messages are often referred to as **selectors**.

Methods can also take parameters, sometimes called *arguments*. A message with a single parameter affixes a colon (`:`) to the name and puts the parameter right after the colon:

```
[myRectangle setWidth:20.0];
```

For methods with multiple parameters, Objective-C's method names are interleaved with the parameters such that the method's name naturally describes the parameters expected by the method. The imaginary message below tells the `myRectangle` object to set its origin to the coordinates (30.0, 50.0):

```
[myRectangle setOriginX: 30.0 y: 50.0]; // This is a good example of  
                                         // multiple parameters
```

A selector name includes all the parts of the name, including the colons, so the selector in the preceding example is named `setOriginX:y:`. It has two colons, because it takes two parameters. The selector name does not, however, include anything else, such as return type or parameter types.

Important The subparts of an Objective-C selector name are not optional, nor can their order be varied. In some languages, the terms “named parameters” and “keyword parameters” carry the implications that the parameters can vary at runtime, can have default values, can be in a different order, and can possibly have additional named parameters. None of these characteristics about parameters are true for Objective-C. For all intents and purposes, an Objective-C method declaration is simply a C function that prepends two additional parameters (see “Messaging” in the *Objective-C Runtime Programming Guide*). Thus, the structure of an Objective-C method declaration differs from the structure of a method that uses named or keyword parameters in a language like Python, as the following Python example illustrates:

```
def func(a, b, NeatMode=SuperNeat, Thing=DefaultThing):  
    pass
```

In this Python example, `Thing` and `NeatMode` might be omitted or might have different values when called.

In principle, a `Rectangle` class could instead implement a `setOrigin::` method with no label for the second parameter, which would be invoked as follows:

```
[myRectangle setOrigin:30.0 :50.0]; // This is a bad example of multiple parameters
```

While syntactically legal, `setOrigin::` does not interleave the method name with the parameters. Thus, the second parameter is effectively unlabeled and it is difficult for a reader of this code to determine the kind or purpose of the method’s parameters.

Methods that take a variable number of parameters are also possible, though they’re somewhat rare. Extra parameters are separated by commas after the end of the method name. (Unlike colons, the commas are not considered part of the name.) In the following example, the imaginary `makeGroup:` method is passed one required parameter (`group`) and three parameters that are optional:

```
[receiver makeGroup:group, memberOne, memberTwo, memberThree];
```

Like standard C functions, methods can return values. The following example sets the variable `isFilled` to YES if `myRectangle` is drawn as a solid rectangle, or NO if it’s drawn in outline form only.

```
BOOL isFilled;  
isFilled = [myRectangle isFilled];
```

Note that a variable and a method can have the same name.

One message expression can be nested inside another. Here, the color of one rectangle is set to the color of another:

```
[myRectangle setPrimaryColor:[otherRect primaryColor]];
```

Objective-C also provides a dot (.) operator that offers a compact and convenient syntax for invoking an object's accessor methods. The dot operator is often used in conjunction with the declared properties feature (see [“Declared Properties”](#) (page 62)) and is described in [“Dot Syntax”](#) (page 17).

Sending Messages to nil

In Objective-C, it is valid to send a message to `nil`—it simply has no effect at runtime. There are several patterns in Cocoa that take advantage of this fact. The value returned from a message to `nil` may also be valid:

- If the method returns an object, then a message sent to `nil` returns `0 (nil)`. For example:

```
Person *motherInLaw = [[aPerson spouse] mother];
```

If the `spouse` object here is `nil`, then `mother` is sent to `nil` and the method returns `nil`.

- If the method returns any pointer type, any integer scalar of size less than or equal to `sizeof(void*)`, a float, a double, a long double, or a long long, then a message sent to `nil` returns `0`.
- If the method returns a `struct`, as defined by the *Mac OS X ABI Function Call Guide* to be returned in registers, then a message sent to `nil` returns `0.0` for every field in the `struct`. Other `struct` data types will not be filled with zeros.
- If the method returns anything other than the aforementioned value types, the return value of a message sent to `nil` is undefined.

The following code fragment illustrates a valid use of sending a message to `nil`.

```
id anObjectMaybeNil = nil;

// this is valid
if ([anObjectMaybeNil methodThatReturnsADouble] == 0.0)
{
    // implementation continues...
}
```

The Receiver's Instance Variables

A method has automatic access to the receiving object's instance variables. You don't need to pass them to the method as parameters. For example, the `primaryColor` method illustrated above takes no parameters, yet it can find the primary color for `otherRect` and return it. Every method assumes the receiver and its instance variables, without having to declare them as parameters.

This convention simplifies Objective-C source code. It also supports the way object-oriented programmers think about objects and messages. Messages are sent to receivers much as letters are delivered to your home. Message parameters bring information from the outside to the receiver; they don't need to bring the receiver to itself.

A method has automatic access only to the receiver's instance variables. If it requires information about a variable stored in another object, it must send a message to the object asking it to reveal the contents of the variable. The `primaryColor` and `isFilled` methods shown earlier are used for just this purpose.

See [“Defining a Class”](#) (page 33) for more information on referring to instance variables.

Polymorphism

As the earlier examples illustrate, messages in Objective-C appear in the same syntactic positions as function calls in standard C. But, because methods “belong to” an object, messages don't behave in the same way that function calls do.

In particular, an object can be operated on by only those methods that were defined for it. It can't confuse them with methods defined for other kinds of object, even if another object has a method with the same name. Therefore, two objects can respond differently to the same message. For example, each kind of object that receives a `display` message could display itself in a unique way. A `Circle` and a `Rectangle` would respond differently to identical instructions to track the cursor.

This feature, referred to as **polymorphism**, plays a significant role in the design of object-oriented programs. Together with dynamic binding, it permits you to write code that might apply to any number of different kinds of objects, without you having to choose at the time you write the code what kinds of objects they might be. They might even be objects that will be developed later, by other programmers working on other projects. If you write code that sends a `display` message to an `id` variable, any object that has a `display` method is a potential receiver.

Dynamic Binding

A crucial difference between function calls and messages is that a function and its parameters are joined together in the compiled code, but a message and a receiving object aren't united until the program is running and the message is sent. Therefore, the exact method invoked to respond to a message can be determined only at runtime, not when the code is compiled.

When a message is sent, a runtime messaging routine looks at the receiver and at the method named in the message. It locates the receiver's implementation of a method matching the name, "calls" the method, and passes it a pointer to the receiver's instance variables. (For more on this routine, see "Messaging" in *Objective-C Runtime Programming Guide*.)

This **dynamic binding** of methods to messages works hand in hand with polymorphism to give object-oriented programming much of its flexibility and power. Because each object can have its own version of a method, an Objective-C statement can achieve a variety of results, not by varying the message but by varying the object that receives the message. Receivers can be decided as the program runs; the choice of receiver can be made dependent on factors such as user actions.

When executing code based upon the Application Kit (**AppKit**), for example, users determine which objects receive messages from menu commands such as Cut, Copy, and Paste. The message goes to whatever object controls the current selection. An object that displays text would react to a `copy` message differently from an object that displays scanned images. An object that represents a set of shapes would respond differently to a `copy` message than a `Rectangle` would. Because messages do not select methods until runtime (from another perspective, because binding of methods to messages does not occur until runtime), these differences in behavior are isolated to the methods themselves. The code that sends the message doesn't have to be concerned with them; it doesn't even have to enumerate the possibilities. An application's objects can each respond in its own way to `copy` messages.

Objective-C takes dynamic binding one step further and allows even the message that's sent (the method selector) to be a variable determined at runtime. This mechanism is discussed in the section "Messaging" in *Objective-C Runtime Programming Guide*.

Dynamic Method Resolution

You can provide implementations of class and instance methods at runtime using dynamic method resolution. See "Dynamic Method Resolution" in *Objective-C Runtime Programming Guide* for more details.

Dot Syntax

Objective-C provides a dot (`.`) operator that offers an alternative to square bracket notation (`[]`) to invoke accessor methods. Dot syntax uses the same pattern that accessing C structure elements uses:

```
myInstance.value = 10;
printf("myInstance value: %d", myInstance.value);
```

When used with objects, however, dot syntax acts as “syntactic sugar”—it is transformed by the compiler into an invocation of an accessor method. Dot syntax does *not* directly get or set an instance variable. The code example above is exactly equivalent to the following:

```
[myInstance setValue:10];
printf("myInstance value: %d", [myInstance value]);
```

As a corollary, if you want to access an object’s own instance variable using accessor methods, you must explicitly call out `self`, for example:

```
self.age = 10;
```

or the equivalent:

```
[self setAge:10];
```

If you do not use `self`, you access the instance variable directly. In the following example, the set accessor method for `age` is *not* invoked:

```
age = 10;
```

If a `nil` value is encountered during property traversal, the result is the same as sending the equivalent message to `nil`. For example, the following pairs are all equivalent:

```
// Each member of the path is an object.
x = person.address.street.name;
x = [[[person address] street] name];

// The path contains a C struct.
// This will crash if window is nil or -contentView returns nil.
y = window.contentView.bounds.origin.y;
y = [[window contentView] bounds].origin.y;
```

```
// An example of using a setter.  
person.address.street.name = @"Oxford Road";  
[[[person address] street] setName: @"Oxford Road"];
```

Classes

An object-oriented program is typically built from a variety of objects. A program based on the Cocoa frameworks might use `NSMatrix` objects, `NSWindow` objects, `NSDictionary` objects, `NSFont` objects, `NSString` objects, and many others. Programs often use more than one object of the same kind or class—several `NSArray` objects or `NSWindow` objects, for example.

In Objective-C, you define objects by defining their class. The class definition is a prototype for a kind of object; it declares the instance variables that become part of every member of the class, and it defines a set of methods that all objects in the class can use.

The compiler creates just one accessible object for each class, a **class object** that knows how to build new objects belonging to the class. (For this reason it's traditionally called a *factory object*.) The class object is the compiled version of the class; the objects it builds are **instances** of the class. The objects that do the main work of your program are instances created by the class object at runtime.

All instances of a class have the same set of methods, and they all have a set of instance variables cut from the same mold. Each object gets its own instance variables, but the methods are shared.

By convention, class names begin with an uppercase letter (such as `Rectangle`); the names of instances typically begin with a lowercase letter (such as `myRectangle`).

Inheritance

Class definitions are additive; each new class that you define is based on another class from which it inherits methods and instance variables. The new class simply adds to or modifies what it inherits. It doesn't need to duplicate inherited code.

Inheritance links all classes together in a hierarchical tree with a single class at its root. When writing code that is based upon the Foundation framework, that root class is typically `NSObject`. Every class (except a root class) has a **superclass** one step nearer the root, and any class (including a root class) can be the superclass for any number of **subclasses** one step farther from the root. Figure 1-1 illustrates the hierarchy for a few of the classes used in a drawing program.

Figure 1-1 Some drawing program classes

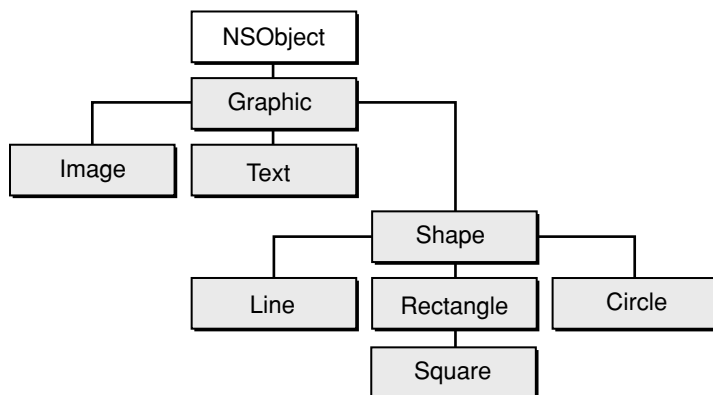


Figure 1-1 shows that the `Square` class is a subclass of the `Rectangle` class, the `Rectangle` class is a subclass of `Shape`, `Shape` is a subclass of `Graphic`, and `Graphic` is a subclass of `NSObject`. Inheritance is cumulative. So a `Square` object has the methods and instance variables defined for `Rectangle`, `Shape`, `Graphic`, and `NSObject`, as well as those defined specifically for `Square`. This is simply to say that an object of type `Square` isn't only a square, it's also a rectangle, a shape, a graphic, and an object of type `NSObject`.

Every class but `NSObject` can thus be seen as a specialization or an adaptation of another class. Each successive subclass further modifies the cumulative total of what's inherited. The `Square` class defines only the minimum needed to turn a rectangle into a square.

When you define a class, you link it to the hierarchy by declaring its superclass; every class you create must be the subclass of another class (unless you define a new root class). Plenty of potential superclasses are available. Cocoa includes the `NSObject` class and several frameworks containing definitions for more than 250 additional classes. Some are classes that you can use off the shelf and incorporate them into your program as is. Others you might want to adapt to your own needs by defining a subclass.

Some framework classes define almost everything you need, but leave some specifics to be implemented in a subclass. You can thus create very sophisticated objects by writing only a small amount of code and reusing work done by the programmers of the framework.

The NSObject Class

`NSObject` is a root class, and so doesn't have a superclass. It defines the basic framework for Objective-C objects and object interactions. It imparts to the classes and instances of classes that inherit from it the ability to behave as objects and cooperate with the runtime system.

A class that doesn't need to inherit any special behavior from another class should nevertheless be made a subclass of the `NSObject` class. Instances of the class must at least have the ability to behave like Objective-C objects at runtime. Inheriting this ability from the `NSObject` class is much simpler and much more reliable than reinventing it in a new class definition.

Note Implementing a new root class is a delicate task and one with many hidden hazards. The class must duplicate much of what the `NSObject` class does, such as allocate instances, connect them to their class, and identify them to the runtime system. For this reason, you should generally use the `NSObject` class provided with Cocoa as the root class. For more information, see *NSObject Class Reference* and the *NSObject Protocol Reference*.

Inheriting Instance Variables

When a class object creates a new instance, the new object contains not only the instance variables that were defined for its class but also the instance variables defined for its superclass and for its superclass's superclass, all the way back to the root class. Thus, the `isa` instance variable defined in the `NSObject` class becomes part of every object. `isa` connects each object to its class.

Figure 1-2 shows some of the instance variables that could be defined for a particular implementation of a `Rectangle` class and where they may come from. Note that the variables that make the object a rectangle are added to the ones that make it a shape, and the ones that make it a shape are added to the ones that make it a graphic, and so on.

Figure 1-2 Rectangle instance variables

Class	<code>isa;</code>	— declared in <code>NSObject</code>
<code>NSPoint</code>	<code>origin;</code>	— declared in <code>Graphic</code>
<code>NSColor</code>	<code>*primaryColor;</code>	} declared in <code>Shape</code>
<code>Pattern</code>	<code>linePattern;</code>	
...		
<code>float</code>	<code>width;</code>	} declared in <code>Rectangle</code>
<code>float</code>	<code>height;</code>	
<code>BOOL</code>	<code>filled;</code>	
<code>NSColor</code>	<code>*fillColor;</code>	
...		

A class doesn't have to declare instance variables. It can simply define new methods and rely on the instance variables it inherits, if it needs any instance variables at all. For example, `Square` might not declare any new instance variables of its own.

Inheriting Methods

An object has access not only to the methods defined for its class but also to methods defined for its superclass, and for its superclass's superclass, all the way back to the root of the hierarchy. For instance, a `Square` object can use methods defined in the `Rectangle`, `Shape`, `Graphic`, and `NSObject` classes as well as methods defined in its own class.

Any new class you define in your program can therefore make use of the code written for all the classes above it in the hierarchy. This type of inheritance is a major benefit of object-oriented programming. When you use one of the object-oriented frameworks provided by Cocoa, your programs can take advantage of the basic functionality coded into the framework classes. You have to add only the code that customizes the standard functionality to your application.

Class objects also inherit from the classes above them in the hierarchy. But because they don't have instance variables (only instances do), they inherit only methods.

Overriding One Method with Another

There's one useful exception to inheritance: When you define a new class, you can implement a new method with the same name as one defined in a class farther up the hierarchy. The new method overrides the original; instances of the new class perform it rather than the original, and subclasses of the new class inherit it rather than the original.

For example, `Graphic` defines a `display` method that `Rectangle` overrides by defining its own version of `display`. The `Graphic` method is available to all kinds of objects that inherit from the `Graphic` class—but not to `Rectangle` objects, which instead perform the `Rectangle` version of `display`.

Although overriding a method blocks the original version from being inherited, other methods defined in the new class can skip over the redefined method and find the original (see [“Messages to self and super”](#) (page 43) to learn how).

A redefined method can also incorporate the very method it overrides. When it does, the new method serves only to refine or modify the method it overrides, rather than replace it outright. When several classes in the hierarchy define the same method, but each new version incorporates the version it overrides, the implementation of the method is effectively spread over all the classes.

Although a subclass can override inherited methods, it can't override inherited instance variables. Because an object has memory allocated for every instance variable it inherits, you can't override an inherited variable by declaring a new one with the same name. If you try, the compiler will complain.

Abstract Classes

Some classes are designed only or primarily so that other classes can inherit from them. These **abstract classes** group methods and instance variables that can be used by a number of subclasses into a common definition. The abstract class is typically incomplete by itself, but contains useful code that reduces the implementation burden of its subclasses. (Because abstract classes must have subclasses to be useful, they're sometimes also called **abstract superclasses**.)

Unlike some other languages, Objective-C does not have syntax to mark classes as abstract, nor does it prevent you from creating an instance of an abstract class.

The `NSObject` class is the canonical example of an abstract class in Cocoa. You never use instances of the `NSObject` class in an application—it wouldn't be good for anything; it would be a generic object with the ability to do nothing in particular.

The `NSView` class, on the other hand, provides an example of an abstract class, instances of which you might occasionally use directly.

Abstract classes often contain code that helps define the structure of an application. When you create subclasses of these classes, instances of your new classes fit effortlessly into the application structure and work automatically with other objects.

Class Types

A class definition is a specification for a kind of object. The class, in effect, defines a data type. The type is based not just on the data structure the class defines (instance variables), but also on the behavior included in the definition (methods).

A class name can appear in source code wherever a type specifier is permitted in C—for example, as an argument to the `sizeof` operator:

```
int i = sizeof(Rectangle);
```

Static Typing

You can use a class name in place of `id` to designate an object's type:

```
Rectangle *myRectangle;
```

Because this way of declaring an object type gives the compiler information about the kind of object it is, it's known as **static typing**. Just as `id` is actually a pointer, objects are statically typed as pointers to a class. Objects are always typed by a pointer. Static typing makes the pointer explicit; `id` hides it.

Static typing permits the compiler to do some type checking—for example, to warn if an object could receive a message that it appears not to be able to respond to—and to loosen some restrictions that apply to objects generically typed `id`. In addition, it can make your intentions clearer to others who read your source code. However, it doesn't defeat dynamic binding or alter the dynamic determination of a receiver's class at runtime.

An object can be statically typed to its own class or to any class that it inherits from. For example, because inheritance makes a `Rectangle` object a kind of `Graphic` object (as shown in the example hierarchy in [Figure 1-1](#) (page 20)), a `Rectangle` instance can be statically typed to the `Graphic` class:

```
Graphic *myRectangle;
```

Static typing to the superclass is possible here because a `Rectangle` object is a `Graphic` object. In addition, it's more than that because it also has the instance variables and method capabilities of `Shape` and `Rectangle` objects, but it's a `Graphic` object nonetheless. For purposes of type checking, given the declaration described here, the compiler considers `myRectangle` to be of type `Graphic`. At runtime, however, if the `myRectangle` object is allocated and initialized as an instance of `Rectangle`, it is treated as one.

See [“Enabling Static Behavior”](#) (page 83) for more on static typing and its benefits.

Type Introspection

Instances can reveal their types at runtime. The `isMemberOfClass:` method, defined in the `NSObject` class, checks whether the receiver is an instance of a particular class:

```
if ( [anObject isMemberOfClass:someClass] )  
    ...
```

The `isKindOfClass:` method, also defined in the `NSObject` class, checks more generally whether the receiver inherits from or is a member of a particular class (whether it has the class in its inheritance path):

```
if ( [anObject isKindOfClass:someClass] )  
    ...
```

The set of classes for which `isKindOfClass:` returns YES is the same set to which the receiver can be statically typed.

Introspection isn't limited to type information. Later sections of this chapter discuss methods that return the class object, report whether an object can respond to a message, and reveal other information.

See *NSObject Class Reference* for more on `isKindOfClass:`, `isMemberOfClass:`, and related methods.

Class Objects

A class definition contains various kinds of information, much of it about instances of the class:

- The name of the class and its superclass
- A template describing a set of instance variables
- The declarations of method names and their return and parameter types
- The method implementations

This information is compiled and recorded in data structures made available to the runtime system. The compiler creates just one object, a **class object**, to represent the class. The class object has access to all the information about the class, which means mainly information about what instances of the class are like. It's able to produce new instances according to the plan put forward in the class definition.

Although a class object keeps the prototype of a class instance, it's not an instance itself. It has no instance variables of its own and it can't perform methods intended for instances of the class. However, a class definition can include methods intended specifically for the class object—**class methods** as opposed to **instance methods**. A class object inherits class methods from the classes above it in the hierarchy, just as instances inherit instance methods.

In source code, the class object is represented by the class name. In the following example, the `Rectangle` class returns the class version number using a method inherited from the `NSObject` class:

```
int versionNumber = [Rectangle version];
```

However, the class name stands for the class object only as the receiver in a message expression. Elsewhere, you need to ask an instance or the class to return the class `id`. Both respond to a `class` message:

```
id aClass = [anObject class];  
id rectClass = [Rectangle class];
```

As these examples show, class objects can, like all other objects, be typed `id`. But class objects can also be more specifically typed to the `Class` data type:

```
Class aClass = [anObject class];  
Class rectClass = [Rectangle class];
```

All class objects are of type `Class`. Using this type name for a class is equivalent to using the class name to statically type an instance.

Class objects are thus full-fledged objects that can be dynamically typed, receive messages, and inherit methods from other classes. They're special only in that they're created by the compiler, lack data structures (instance variables) of their own other than those built from the class definition, and are the agents for producing instances at runtime.

Note The compiler also builds a metaclass object for each class. It describes the class object just as the class object describes instances of the class. But while you can send messages to instances and to the class object, the metaclass object is used only internally by the runtime system.

Creating Instances

A principal function of a class object is to create new instances. This code tells the `Rectangle` class to create a new rectangle instance and assign it to the `myRectangle` variable:

```
id myRectangle;  
myRectangle = [Rectangle alloc];
```

The `alloc` method dynamically allocates memory for the new object's instance variables and initializes them all to 0—all, that is, except the `isa` variable that connects the new instance to its class. For an object to be useful, it generally needs to be more completely initialized. That's the function of an `init` method. Initialization typically follows immediately after allocation:

```
myRectangle = [[Rectangle alloc] init];
```

This line of code, or one like it, would be necessary before `myRectangle` could receive any of the messages that were illustrated in previous examples in this chapter. The `alloc` method returns a new instance and that instance performs an `init` method to set its initial state. Every class object has at least one method (like `alloc`) that enables it to produce new objects, and every instance has at least one method (like `init`) that prepares it for use. Initialization methods often take parameters to allow particular values to be passed and have keywords to label the parameters (`initWithPosition:size:`, for example, is a method that might initialize a new `Rectangle` instance), but every initialization method begins with “`init`”.

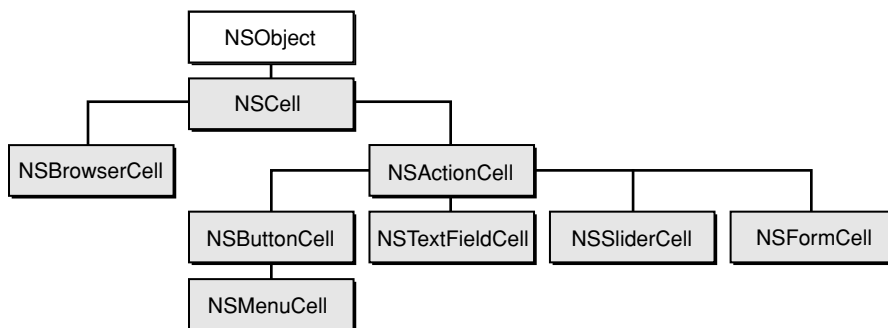
Customization with Class Objects

It's not just a whim of the Objective-C language that classes are treated as objects. It's a choice that has intended, and sometimes surprising, benefits for design. It's possible, for example, to customize an object with a class, where the class belongs to an open-ended set. In AppKit, for example, an `NSMatrix` object can be customized with a particular kind of `NSCell` object.

An `NSMatrix` object can take responsibility for creating the individual objects that represent its cells. It can do this when the matrix is first initialized and later when new cells are needed. The visible matrix that an `NSMatrix` object draws on the screen can grow and shrink at runtime, perhaps in response to user actions. When it grows, the matrix needs to be able to produce new objects to fill the new slots that are added.

But what kind of objects should they be? Each matrix displays just one kind of `NSCell`, but there are many different kinds. The inheritance hierarchy in Figure 1-3 shows some of those provided by AppKit. All inherit from the generic `NSCell` class.

Figure 1-3 The inheritance hierarchy for `NSCell`



When a matrix creates `NSCell` objects, should they be `NSButtonCell` objects to display a bank of buttons or switches, `NSTextFieldCell` objects to display fields where the user can enter and edit text, or some other kind of `NSCell`? The `NSMatrix` object must allow for any kind of cell, even types that haven't been invented yet.

One solution to this problem would be to define the `NSMatrix` class as abstract and require everyone who uses it to declare a subclass and implement the methods that produce new cells. Because they would be implementing the methods, users could make certain that the objects they created were of the right type.

But this solution would require users of the `NSMatrix` class to do work that ought to be done in the `NSMatrix` class itself, and it unnecessarily proliferates the number of classes. Because an application might need more than one kind of matrix, each with a different kind of cell, it could become cluttered with `NSMatrix` subclasses. Every time you invented a new kind of `NSCell`, you'd also have to define a new kind of `NSMatrix`. Moreover, programmers on different projects would be writing virtually identical code to do the same job, all to make up for the failure of `NSMatrix` to do it.

A better solution, and the solution the `NSMatrix` class adopts, is to allow `NSMatrix` instances to be initialized with a kind of `NSCell`—that is, with a class object. The `NSMatrix` class also defines a `setCellClass:` method that passes the class object for the kind of `NSCell` object an `NSMatrix` should use to fill empty slots:

```
[myMatrix setCellClass:[NSButtonCell class]];
```

The `NSMatrix` object uses the class object to produce new cells when it's first initialized and whenever it's resized to contain more cells. This kind of customization would be difficult if classes weren't objects that could be passed in messages and assigned to variables.

Variables and Class Objects

When you define a new class, you can specify instance variables. Every instance of the class can maintain its own copy of the variables you declare—each object controls its own data. There is, however, no class variable counterpart to an instance variable. Only internal data structures, initialized from the class definition, are provided for the class. Moreover, a class object has no access to the instance variables of any instances; it can't initialize, read, or alter them.

For all the instances of a class to share data, you must define an external variable of some sort. The simplest way to do this is to declare a variable in the class implementation file:

```
int MCLSGlobalVariable;

@implementation MyClass
// implementation continues
```

In a more sophisticated implementation, you can declare a variable to be `static`, and provide class methods to manage it. Declaring a variable `static` limits its scope to just the class—and to just the part of the class that's implemented in the file. (Thus unlike instance variables, static variables cannot be inherited by, or directly manipulated by, subclasses.) This pattern is commonly used to define shared instances of a class (such as singletons; see “Creating a Singleton Instance” in *Cocoa Fundamentals Guide*).

```
static MyClass *MCLSSharedInstance;

@implementation MyClass

+ (MyClass *)sharedInstance
{
```

```
// check for existence of shared instance
// create if necessary
return MCLSSharedInstance;
}
// implementation continues
```

Static variables help give the class object more functionality than just that of a **factory** producing instances; it can approach being a complete and versatile object in its own right. A class object can be used to coordinate the instances it creates, dispense instances from lists of objects already created, or manage other processes essential to the application. In the case when you need only one object of a particular class, you can put all the object's state into static variables and use only class methods. This saves the step of allocating and initializing an instance.

Note It is also possible to use external variables that are not declared `static`, but the limited scope of static variables better serves the purpose of encapsulating data into separate objects.

Initializing a Class Object

If you want to use a class object for anything besides allocating instances, you may need to initialize it just as you would an instance. Although programs don't allocate class objects, Objective-C does provide a way for programs to initialize them.

If a class makes use of static or global variables, the `initialize` method is a good place to set their initial values. For example, if a class maintains an array of instances, the `initialize` method could set up the array and even allocate one or two default instances to have them ready.

The runtime system sends an `initialize` message to every class object before the class receives any other messages and after its superclass has received the `initialize` message. This sequence gives the class a chance to set up its runtime environment before it's used. If no initialization is required, you don't need to write an `initialize` method to respond to the message.

Because of inheritance, an `initialize` message sent to a class that doesn't implement the `initialize` method is forwarded to the superclass, even though the superclass has already received the `initialize` message. For example, assume class A implements the `initialize` method, and class B inherits from class A but does not implement the `initialize` method. Just before class B is to receive its first message, the runtime system sends `initialize` to it. But, because class B doesn't implement `initialize`, class A's `initialize` is executed instead. Therefore, class A should ensure that its initialization logic is performed only once, and for the appropriate class.

To avoid performing initialization logic more than once, use the template in Listing 1-1 when implementing the `initialize` method.

Listing 1-1 Implementation of the `initialize` method

```
+ (void)initialize
{
    if (self == [ThisClass class]) {
        // Perform initialization here.
        ...
    }
}
```

Note Remember that the runtime system sends `initialize` to each class individually. Therefore, in a class's implementation of the `initialize` method, you must not send the `initialize` message to its superclass.

Methods of the Root Class

All objects, classes and instances alike, need an interface to the runtime system. Both class objects and instances should be able to introspect about their abilities and to report their place in the inheritance hierarchy. It's the province of the `NSObject` class to provide this interface.

So that `NSObject` methods don't have to be implemented twice—once to provide a runtime interface for instances and again to duplicate that interface for class objects—class objects are given special dispensation to perform instance methods defined in the root class. When a class object receives a message that it can't respond to with a class method, the runtime system determines whether there's a root instance method that can respond. The only instance methods that a class object can perform are those defined in the root class, and only if there's no class method that can do the job.

For more on this peculiar ability of class objects to perform root instance methods, see *NSObject Class Reference*.

Class Names in Source Code

In source code, class names can be used in only two very different contexts. These contexts reflect the dual role of a class as a data type and as an object:

- The class name can be used as a type name for a kind of object. For example:

```
Rectangle *anObject;
```

Here `anObject` is statically typed to be a pointer to a `Rectangle` object. The compiler expects it to have the data structure of a `Rectangle` instance and to have the instance methods defined and inherited by the `Rectangle` class. Static typing enables the compiler to do better type checking and makes source code more self-documenting. See [“Enabling Static Behavior”](#) (page 83) for details.

Only instances can be statically typed; class objects can’t be, because they aren’t members of a class, but rather belong to the `Class` data type.

- As the receiver in a message expression, the class name refers to the class object. This usage was illustrated in several of the earlier examples. The class name can stand for the class object only as a message receiver. In any other context, you must ask the class object to reveal its `id` (by sending it a `class` message). This example passes the `Rectangle` class as a parameter in an `isKindOfClass:` message:

```
if ( [anObject isKindOfClass:[Rectangle class]] )  
    ...
```

It would have been illegal to simply use the name “`Rectangle`” as the parameter. The class name can only be a receiver.

If you don’t know the class name at compile time but have it as a string at runtime, you can use `NSClassFromString` to return the class object:

```
NSString *className;  
...  
if ( [anObject isKindOfClass:NSClassFromString(className)] )  
    ...
```

This function returns `nil` if the string it’s passed is not a valid class name.

Class names exist in the same namespace as global variables and function names. A class and a global variable can’t have the same name. Class names are the only names with global visibility in Objective-C.

Testing Class Equality

You can test two class objects for equality using a direct pointer comparison. It is important, though, to get the correct class. There are several features in the Cocoa frameworks that dynamically and transparently subclass existing classes to extend their functionality (for example, key-value observing and Core Data do this—see *Key-Value Observing Programming Guide* and *Core Data Programming Guide* respectively). In a

dynamically-created subclass, the `class` method is typically overridden such that the subclass masquerades as the class it replaces. When testing for class equality, you should therefore compare the values returned by the `class` method rather than those returned by lower-level functions. Put in terms of API, the following inequalities pertain for dynamic subclasses:

```
[object class] != object_getClass(object) != *((Class*)object)
```

You should therefore test two classes for equality as follows:

```
if ([objectA class] == [objectB class]) { //...
```


Defining a Class

Much of object-oriented programming consists of writing the code for new objects—defining new classes. In Objective-C, classes are defined in two parts:

- An **interface** that declares the methods and properties of the class and names its superclass
- An **implementation** that actually defines the class (contains the code that implements its methods)

Each of these parts is typically in its own file. Sometimes, however, a class definition spans several files through the use of a feature called a *category*. Categories can compartmentalize a class definition or extend an existing one. Categories are described in [“Categories and Extensions”](#) (page 73).

Source Files

Although the compiler doesn’t require it, class interface and implementation are usually in two different files. The interface file must be made available to anyone who uses the class.

A single file can declare or implement more than one class. Nevertheless, it’s customary to have a separate interface file for each class, if not also a separate implementation file. Keeping class interfaces separate better reflects their status as independent entities.

Interface and implementation files typically are named after the class. The name of the implementation file has the `.m` extension, indicating that it contains Objective-C source code. The interface file can be assigned any other extension. Because it’s included in other source files, the name of the interface file usually has the `.h` extension typical of header files. For example, the `Rectangle` class would be declared in `Rectangle.h` and defined in `Rectangle.m`.

Separating an object’s interface from its implementation fits well with the design of object-oriented programs. An object is a self-contained entity that can be viewed from the outside almost as a black box. Once you’ve determined how an object interacts with other elements in your program—that is, once you’ve declared its interface—you can freely alter its implementation without affecting any other part of the application.

Class Interface

The declaration of a class interface begins with the compiler directive `@interface` and ends with the directive `@end`. (All Objective-C directives to the compiler begin with “@”)

```
@interface ClassName : ItsSuperclass
// Method and property declarations.
@end
```

The first line of the declaration presents the new class name and links it to its superclass. The superclass defines the position of the new class in the inheritance hierarchy, as discussed under [“Inheritance”](#) (page 19).

Methods and properties for the class are declared next, before the end of the class declaration. The names of methods that can be used by class objects, **class methods**, are preceded by a plus sign:

```
+ alloc;
```

The methods that instances of a class can use, **instance methods**, are marked with a minus sign:

```
- (void)display;
```

Although it’s not a common practice, you can define a class method and an instance method with the same name. A method can also have the same name as an instance variable, which is more common, especially if the method returns the value in the variable. For example, `Circle` has a `radius` method that could match a `radius` instance variable.

Method return types are declared using the standard C syntax for casting one type to another:

```
- (float)radius;
```

Parameter types are declared in the same way:

```
- (void)setRadius:(float)aRadius;
```

If a return or parameter type isn’t explicitly declared, it’s assumed to be the default type for methods and messages—an `id`. The `alloc` method illustrated earlier returns `id`.

When there’s more than one parameter, the parameters are declared within the method name after the colons. Parameters break the name apart in the declaration, just as in a message. For example:

```
- (void)setWidth:(float)width height:(float)height;
```

Methods that take a variable number of parameters declare them using a comma and ellipsis points, just as a function would:

```
- makeGroup:group, ...;
```

Property declarations take the form:

```
@property (attributes) Type propertyName;
```

Properties are discussed in more detail in [“Declared Properties”](#) (page 62).

Note Historically, the interface required declarations of a class’s **instance variables**, the data structures that are part of each instance of the class. These were declared in braces after the `@interface` declaration and before method declarations:

```
@interface ClassName : ItsSuperclass
{
    // Instance variable declarations.
}
// Method and property declarations.
@end
```

Instance variables represent an implementation detail, and should typically not be accessed outside of the class itself. Moreover, you can declare them in the implementation block or synthesize them using declared properties. Typically you should not, therefore, declare instance variables in the public interface and so you should omit the braces.

Importing the Interface

The interface file must be included in any source module that depends on the class interface—that includes any module that creates an instance of the class, sends a message to invoke a method declared for the class, or mentions an instance variable declared in the class. The interface is usually included with the `#import` directive:

```
#import "Rectangle.h"
```

This directive is identical to `#include`, except that it makes sure that the same file is never included more than once. It's therefore preferred and is used in place of `#include` in code examples throughout Objective-C–based documentation.

To reflect the fact that a class definition builds on the definitions of inherited classes, an interface file begins by importing the interface for its superclass:

```
#import "ItsSuperclass.h"

@interface ClassName : ItsSuperclass
// Method and property declarations.
@end
```

This convention means that every interface file includes, indirectly, the interface files for all inherited classes. When a source module imports a class interface, it gets interfaces for the entire inheritance hierarchy that the class is built upon.

Note that if there is a **precomp**—a precompiled header—that supports the superclass, you may prefer to import the precomp instead.

Referring to Other Classes

An interface file declares a class and, by importing its superclass, implicitly contains declarations for all inherited classes, from `NSObject` on down through its superclass. If the interface mentions classes not in this hierarchy, it must import them explicitly or declare them with the `@class` directive:

```
@class Rectangle, Circle;
```

This directive simply informs the compiler that “Rectangle” and “Circle” are class names. It doesn't import their interface files.

An interface file mentions class names when it statically types instance variables, return values, and parameters. For example, this declaration

```
- (void)setPrimaryColor:(NSColor *)aColor;
```

mentions the `NSColor` class.

Because declarations like this simply use the class name as a type and don't depend on any details of the class interface (its methods and instance variables), the `@class` directive gives the compiler sufficient forewarning of what to expect. However, when the interface to a class is actually used (instances created, messages sent), the class interface must be imported. Typically, an interface file uses `@class` to declare classes, and the corresponding implementation file imports their interfaces (since it needs to create instances of those classes or send them messages).

The `@class` directive minimizes the amount of code seen by the compiler and linker, and is therefore the simplest way to give a forward declaration of a class name. Being simple, it avoids potential problems that may come with importing files that import still other files. For example, if one class declares a statically typed instance variable of another class, and their two interface files import each other, neither class may compile correctly.

The Role of the Interface

The purpose of the interface file is to declare the new class to other source modules (and to other programmers). It contains information they need to work with the class (programmers might also appreciate a little documentation).

- The interface file tells users how the class is connected into the inheritance hierarchy and what other classes—inherited or simply referred to somewhere in the class—are needed.
- Through its list of method declarations, the interface file lets other modules know what messages can be sent to the class object and instances of the class. Every method that can be used outside the class definition is declared in the interface file; methods that are internal to the class implementation can be omitted.

Class Implementation

The definition of a class is structured very much like its declaration. It begins with an `@implementation` directive and ends with the `@end` directive. In addition, the class may declare instance variables in braces after the `@implementation` directive:

```
@implementation ClassName
{
    // Instance variable declarations.
}
// Method definitions.
@end
```

Instance variables are often specified by declared properties (see [“Declared Properties”](#) (page 62)). If you don’t declare additional instance variables, you can omit the braces:

```
@implementation ClassName
// Method definitions.
@end
```

Note Every implementation file must import its own interface. For example, `Rectangle.m` imports `Rectangle.h`. Because the implementation doesn’t need to repeat any of the declarations it imports, it can safely omit the name of the superclass.

Methods for a class are defined, like C functions, within a pair of braces. Before the braces, they’re declared in the same manner as in the interface file, but without the semicolon. For example:

```
+ (id)alloc {
    ...
}

- (BOOL)isFilled {
    ...
}

- (void)setFilled:(BOOL)flag {
    ...
}
```

Methods that take a variable number of parameters handle them just as a function would:

```
#import <stdarg.h>

...

- getGroup:group, ... {

    va_list ap;
```

```
        va_start(ap, group);  
        ...  
    }
```

Referring to Instance Variables

By default, the definition of an instance method has all the instance variables of the object within its scope. It can refer to them simply by name. Although the compiler creates the equivalent of C structures to store instance variables, the exact nature of the structure is hidden. You don't need either of the structure operators (`.` or `->`) to refer to an object's data. For example, this method definition refers to the receiver's `filled` instance variable:

```
- (void)setFilled:(BOOL)flag  
{  
    filled = flag;  
    ...  
}
```

Neither the receiving object nor its `filled` instance variable is declared as a parameter to this method, yet the instance variable falls within its scope. This simplification of method syntax is a significant shorthand in the writing of Objective-C code.

When the instance variable belongs to an object that's not the receiver, the object's type must be made explicit to the compiler through static typing. In referring to the instance variable of a statically typed object, the structure pointer operator (`->`) is used.

Suppose, for example, that the `Sibling` class declares a statically typed object, `twin`, as an instance variable:

```
@interface Sibling : NSObject  
{  
    Sibling *twin;  
    int gender;  
    struct features *appearance;  
}
```

As long as the instance variables of the statically typed object are within the scope of the class (as they are here because `twin` is typed to the same class), a `Sibling` method can set them directly:

```
- makeIdenticalTwin
{
    if ( !twin ) {
        twin = [[Sibling alloc] init];
        twin->gender = gender;
        twin->appearance = appearance;
    }
    return twin;
}
```

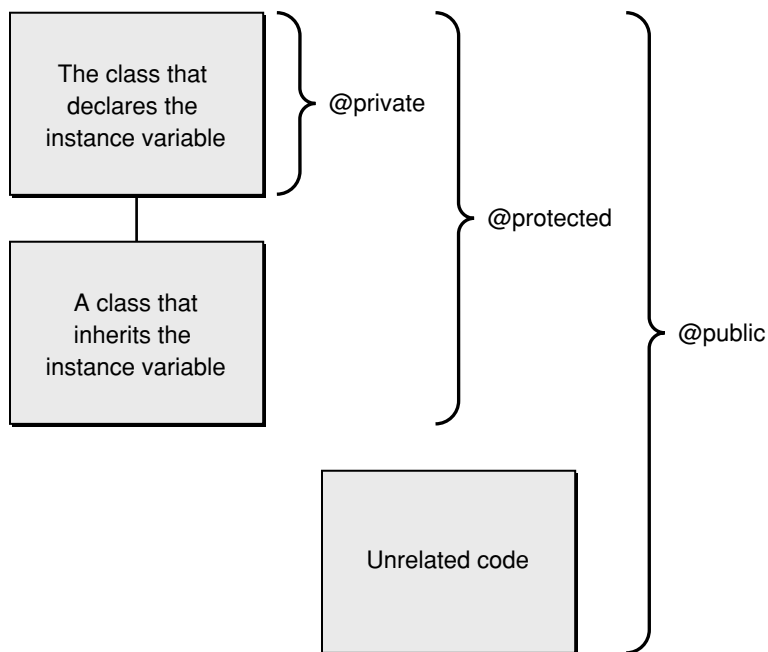
The Scope of Instance Variables

To enforce the ability of an object to hide its data, the compiler limits the scope of instance variables—that is, limits their visibility within the program. But to provide flexibility, it also lets you explicitly set the scope at four levels. Each level is marked by a compiler directive:

Directive	Meaning
@private	The instance variable is accessible only within the class that declares it.
@protected	The instance variable is accessible within the class that declares it and within classes that inherit it. All instance variables without an explicit scope directive have @protected scope.
@public	The instance variable is accessible everywhere.
@package	Using the modern runtime, an @package instance variable has @public scope inside the executable image that implements the class, but acts like @private outside. The @package scope for Objective-C instance variables is analogous to <code>private_extern</code> for C variables and functions. Any code outside the class implementation's image that tries to use the instance variable gets a link error. This scope is most useful for instance variables in framework classes, where @private may be too restrictive but @protected or @public too permissive.

Figure 2-1 illustrates the levels of scoping.

Figure 2-1 The scope of instance variables (@package scope not shown)



A scoping directive applies to all the instance variables listed after it, up to the next directive or the end of the list. In the following example, the `age` and `evaluation` instance variables are private; `name`, `job`, and `wage` are protected; and `boss` is public.

```
@interface Worker : NSObject
{
    char *name;
    @private
    int age;
    char *evaluation;
    @protected
    id job;
    float wage;
    @public
    id boss;
}
```

By default, all unmarked instance variables (like `name` above) are `@protected`.

All instance variables that a class declares, no matter how they're marked, are within the scope of the class definition. For example, a class that declares a `job` instance variable, such as the `Worker` class shown above, can refer to it in a method definition:

```
- promoteTo:newPosition
{
    id old = job;
    job = newPosition;
    return old;
}
```

Obviously, if a class couldn't access its own instance variables, the instance variables would be of no use whatsoever.

Normally, a class also has access to the instance variables it inherits. The ability to refer to an instance variable is usually inherited along with the variable. It makes sense for classes to have their entire data structures within their scope, especially if you think of a class definition as merely an elaboration of the classes it inherits from. The `promoteTo:` method illustrated earlier could just as well have been defined in any class that inherits the `job` instance variable from the `Worker` class.

However, there are reasons why you might want to restrict inheriting classes from directly accessing an instance variable:

- Once a subclass accesses an inherited instance variable, the class that declares the variable is tied to that part of its implementation. In later versions, it can't eliminate the variable or alter the role it plays without inadvertently breaking the subclass.
- Moreover, if a subclass accesses an inherited instance variable and alters its value, it may inadvertently introduce bugs in the class that declares the variable, especially if the variable is involved in class-internal dependencies.

To limit an instance variable's scope to just the class that declares it, you must mark it `@private`. Instance variables marked `@private` are only available to subclasses by calling public accessor methods, if they exist.

At the other extreme, marking a variable `@public` makes it generally available, even outside of class definitions that inherit or declare the variable. Normally, to get information stored in an instance variable, other objects must send a message requesting it. However, a public instance variable can be accessed anywhere as if it were a field in a C structure. For example:

```
Worker *ceo = [[Worker alloc] init];
```

```
ceo->boss = nil;
```

Note that the object must be statically typed.

Marking instance variables `@public` defeats the ability of an object to hide its data. It runs counter to a fundamental principle of object-oriented programming—the encapsulation of data within objects where it's protected from view and inadvertent error. Public instance variables should therefore be avoided except in extraordinary cases.

Messages to self and super

Objective-C provides two terms that can be used within a method definition to refer to the object that performs the method—`self` and `super`.

Suppose, for example, that you define a `reposition` method that needs to change the coordinates of whatever object it acts on. It can invoke the `setOrigin::` method to make the change. All it needs to do is send a `setOrigin::` message to the same object that the `reposition` message itself was sent to. When you're writing the reposition code, you can refer to that object as either `self` or `super`. The `reposition` method could read either:

```
- reposition
{
    ...
    [self setOrigin:someX :someY];
    ...
}
```

or:

```
- reposition
{
    ...
    [super setOrigin:someX :someY];
    ...
}
```

Here, `self` and `super` both refer to the object receiving a `reposition` message, whatever object that may happen to be. The two terms are quite different, however. `self` is one of the hidden parameters that the messaging routine passes to every method; it's a local variable that can be used freely within a method implementation, just as the names of instance variables can be. `super` is a term that substitutes for `self` only as the receiver in a message expression. As receivers, the two terms differ principally in how they affect the messaging process:

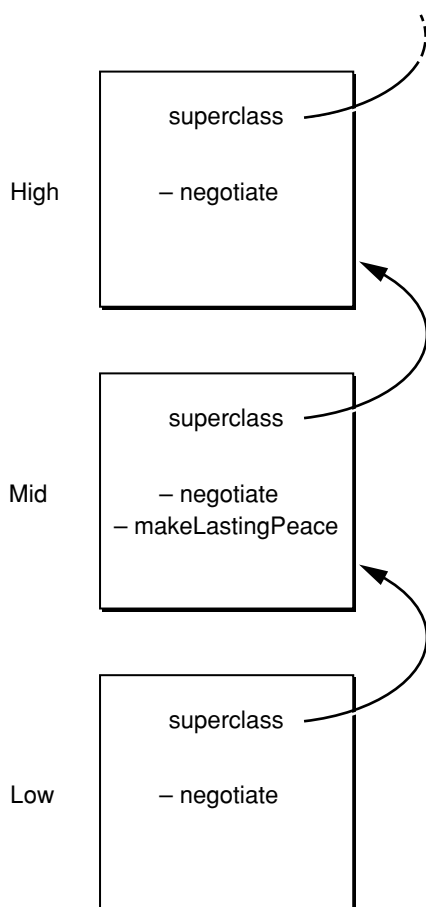
- `self` searches for the method implementation in the usual manner, starting in the **dispatch table** of the receiving object's class. In the example above, it would begin with the class of the object receiving the `reposition` message.
- `super` is a flag that tells the compiler to search for the method implementation in a very different place. It begins in the superclass of the class that defines the method where `super` appears. In the example above, it would begin with the superclass of the class where `reposition` is defined.

Wherever `super` receives a message, the compiler substitutes another messaging routine for the `objc_msgSend` function. The substitute routine looks directly to the superclass of the defining class—that is, to the superclass of the class sending the message to `super`—rather than to the class of the object receiving the message.

An Example: Using `self` and `super`

The difference between `self` and `super` becomes clear when using a hierarchy of three classes. Suppose, for example, that we create an object belonging to a class called `Low`. The superclass of `Low` is `Mid`; the superclass of `Mid` is `High`. All three classes define a method called `negotiate`, which each class uses for its own purpose. In addition, `Mid` defines an ambitious method called `makeLastingPeace`, which itself employs the `negotiate` method. The classes and those methods are illustrated in Figure 2-2.

Figure 2-2 The hierarchy of `High`, `Mid`, and `Low`



Suppose that the implementation of `makeLastingPeace` (in the `Mid` class) uses `self` to indicate the object to send the `negotiate` message to:

```
- makeLastingPeace
{
    [self negotiate];
    ...
}
```

```
}
```

When a message is sent to a `Low` object to perform the `makeLastingPeace` method, `makeLastingPeace` sends a `negotiate` message to the same `Low` object. The messaging routine finds the version of `negotiate` defined in `Low`, the class of `self`.

However, if the implementation of `makeLastingPeace` instead uses `super` as the receiver,

```
- makeLastingPeace
{
    [super negotiate];
    ...
}
```

the messaging routine finds the version of `negotiate` defined in `High`. It ignores the class (`Low`) of the object that received the `makeLastingPeace` message and skips to the superclass of `Mid`, because `Mid` is where `makeLastingPeace` is defined. Neither implementation finds the `Mid` version of `negotiate`.

As this example illustrates, `super` provides a way to bypass a method that overrides another method. Here, the use of `super` enabled `makeLastingPeace` to bypass the `Mid` version of `negotiate` that redefined the `High` version of that method.

Not being able to reach the `Mid` version of `negotiate`, as just described, may seem like a flaw, but under the circumstances it's intentional:

- The author of the `Low` class intentionally overrode the `Mid` version of `negotiate` so that instances of `Low` (and its subclasses) would invoke the redefined version of the method instead. The designer of `Low` didn't want `Low` objects to perform the inherited method.
- The author of the `Mid` method `makeLastingPeace`, in sending the `negotiate` message to `super` (as shown in the second implementation), intentionally skipped over the `Mid` version of `negotiate` (and over any versions that might be defined in classes like `Low` that inherit from `Mid`) to perform the version defined in the `High` class. The designer of the second implementation of `makeLastingPeace` wanted to use the `High` version of `negotiate` and no other.

The `Mid` version of `negotiate` could still be used, but it would take a direct message to a `Mid` instance to do so.

Using super

Messages to `super` allow method implementations to be distributed over more than one class. You can override an existing method to modify or add to it and still incorporate the original method in the modification:

```
- negotiate
{
    ...
    return [super negotiate];
}
```

For some tasks, each class in the inheritance hierarchy can implement a method that does part of the job and passes the message on to `super` for the rest. The `init` method, which initializes a newly allocated instance, is designed to work like this. Each `init` method has responsibility for initializing the instance variables defined in its class. But before doing so, it sends an `init` message to `super` to have the classes it inherits from initialize their instance variables. Each version of `init` follows this procedure, so classes initialize their instance variables in the order of inheritance:

```
- (id)init
{
    self = [super init];
    if (self) {
        ...
    }
}
```

It's also possible to concentrate core functionality in one method defined in a superclass and have subclasses incorporate the method through messages to `super`. For example, every class method that creates an instance must allocate storage for the new object and initialize its `isa` variable to the class structure. Allocation is typically left to the `alloc` and `allocWithZone:` methods defined in the `NSObject` class. If another class overrides these methods (a rare case), it can still get the basic functionality by sending a message to `super`.

Redefining self

`super` is simply a flag to the compiler telling it where to begin searching for the method to perform; it's used only as the receiver of a message. But `self` is a variable name that can be used in any number of ways, even assigned a new value.

There's a tendency to do just that in definitions of class methods. Class methods are often concerned not with the class object, but with instances of the class. For example, many class methods combine allocation and initialization of an instance, often setting up instance variable values at the same time. In such a method, it might be tempting to send messages to the newly allocated instance and to call the instance `self`, just as in an instance method. But that would be an error. `self` and `super` both refer to the receiving object—the object that gets a message telling it to perform the method. Inside an instance method, `self` refers to the instance; but inside a class method, `self` refers to the class object. This is an example of what *not* to do:

```
+ (Rectangle *)rectangleOfColor:(NSColor *) color
{
    self = [[Rectangle alloc] init]; // BAD
    [self setColor:color];
    return self;
}
```

To avoid confusion, it's usually better to use a variable other than `self` to refer to an instance inside a class method:

```
+ (id)rectangleOfColor:(NSColor *)color
{
    id newInstance = [[Rectangle alloc] init]; // GOOD
    [newInstance setColor:color];
    return newInstance;
}
```

In fact, rather than sending the `alloc` message to the class in a class method, it's often better to send `alloc` to `self`. This way, if the class is subclassed, and the `rectangleOfColor:` message is received by a subclass, the instance returned is the same type as the subclass (for example, the `array` method of `NSArray` is inherited by `NSMutableArray`).

```
+ (id)rectangleOfColor:(NSColor *)color
{
    id newInstance = [[self alloc] init]; // EXCELLENT
    [newInstance setColor:color];
    return newInstance;
}
```


See “Creating and Initializing Objects” for more information about implementing initializer and related methods.

Protocols

Protocols declare methods that can be implemented by any class. Protocols are useful in at least three situations:

- To declare methods that others are expected to implement
- To declare the **interface** to an object while concealing its class
- To capture similarities among classes that are not hierarchically related

Declaring Interfaces for Others to Implement

Class and category interfaces declare methods that are associated with a particular class—mainly methods that the class implements. Informal and formal **protocols**, on the other hand, declare methods that are independent of any specific class, but which any class, and perhaps many classes, might implement.

A protocol is simply a list of method declarations, unattached to a class definition. For example, these methods that report user actions on the mouse could be gathered into a protocol:

```
- (void)mouseDown:(NSEvent *)theEvent;  
- (void)mouseDragged:(NSEvent *)theEvent;  
- (void)mouseUp:(NSEvent *)theEvent;
```

Any class that wanted to respond to mouse **events** could adopt the protocol and implement its methods.

Protocols free method declarations from dependency on the class hierarchy, so they can be used in ways that classes and categories cannot. Protocols list methods that are (or may be) implemented somewhere, but the identity of the class that implements them is not of interest. What is of interest is whether or not a particular class **conforms** to the protocol—whether it has implementations of the methods the protocol declares. Thus objects can be grouped into types not just on the basis of similarities resulting from inheriting from the same class, but also on the basis of their similarity in conforming to the same protocol. Classes in unrelated branches of the inheritance hierarchy might be typed alike because they conform to the same protocol.

Protocols can play a significant role in object-oriented design, especially when a project is divided among many implementors or it incorporates objects developed in other projects. Cocoa software uses protocols heavily to support interprocess communication through Objective-C messages.

However, an Objective-C program doesn't need to use protocols. Unlike class definitions and message expressions, they're optional. Some Cocoa frameworks use them; some don't. It all depends on the task at hand.

Methods for Others to Implement

If you know the class of an object, you can look at its interface declaration (and the interface declarations of the classes it inherits from) to find what messages it responds to. These declarations advertise the messages it can receive. Protocols provide a way for it to also advertise the messages it sends.

Communication works both ways; objects send messages as well as receive them. For example, an object might delegate responsibility for a certain operation to another object, or it may on occasion simply need to ask another object for information. In some cases, an object might be willing to notify other objects of its actions so that they can take whatever collateral measures might be required.

If you develop the class of the sender and the class of the receiver as part of the same project (or if someone else has supplied you with the receiver and its interface file), this communication is easily coordinated. The sender simply imports the interface file of the receiver. The imported file declares the method selectors the sender uses in the messages it sends.

However, if you develop an object that sends messages to objects that aren't yet defined—objects that you're leaving for others to implement—you won't have the receiver's interface file. You need another way to declare the methods you use in messages but don't implement. A protocol serves this purpose. It informs the compiler about methods the class uses and also informs other implementors of the methods they need to define to have their objects work with yours.

Suppose, for example, that you develop an object that asks for the assistance of another object by sending it `helpOut:` and other messages. You provide an `assistant` instance variable to record the **outlet** for these messages and define a companion method to set the instance variable. This method lets other objects register themselves as potential recipients of your object's messages:

```
- setAssistant:anObject
{
    assistant = anObject;
}
```

Then, whenever a message is to be sent to the `assistant`, a check is made to be sure that the receiver implements a method that can respond:

```
- (BOOL)doWork
{
    ...
    if ( [assistant respondsToSelector:@selector(helpOut:)] ) {
        [assistant helpOut:self];
        return YES;
    }
    return NO;
}
```

Because, at the time you write this code, you can't know what kind of object might register itself as the `assistant`, you can only declare a protocol for the `helpOut:` method; you can't import the interface file of the class that implements it.

Declaring Interfaces for Anonymous Objects

A protocol can be used to declare the methods of an **anonymous object**, an object of unknown class. An anonymous object may represent a service or handle a limited set of functions, especially when only one object of its kind is needed. (Objects that play a fundamental role in defining an application's architecture and objects that you must initialize before using are not good candidates for anonymity.)

Objects are not anonymous to their developers, of course, but they are anonymous when the developer supplies them to someone else. For example, consider the following situations:

- Someone who supplies a framework or a suite of objects for others to use can include objects that are not identified by a class name or an interface file. Lacking the name and class interface, users have no way of creating instances of the class. Instead, the supplier must provide a ready-made instance. Typically, a method in another class returns a usable object:

```
id formatter = [receiver formattingService];
```

The object returned by the method is an object without a class identity, at least not one the supplier is willing to reveal. For it to be of any use at all, the supplier must be willing to identify at least some of the messages that it can respond to. The messages are identified by associating the object with a list of methods declared in a protocol.

- You can send Objective-C messages to **remote objects**—objects in other applications.

Each application has its own structure, classes, and internal logic. But you don't need to know how another application works or what its components are to communicate with it. As an outsider, all you need to know is what messages you can send (the protocol) and where to send them (the receiver).

An application that publishes one of its objects as a potential receiver of **remote messages** must also publish a protocol declaring the methods the object will use to respond to those messages. It doesn't have to disclose anything else about the object. The sending application doesn't need to know the class of the object or use the class in its own design. All it needs is the protocol.

Protocols make anonymous objects possible. Without a protocol, there would be no way to declare an interface to an object without identifying its class.

Note Even though the supplier of an anonymous object doesn't reveal its class, the object itself reveals it at runtime. A class message returns the anonymous object's class. However, there's usually little point in discovering this extra information; the information in the protocol is sufficient.

Nonhierarchical Similarities

If more than one class implements a set of methods, those classes are often grouped under an abstract class that declares the methods they have in common. Each subclass can reimplement the methods in its own way, but the inheritance hierarchy and the common declaration in the abstract class capture the essential similarity between the subclasses.

However, sometimes it's not possible to group common methods in an abstract class. Classes that are unrelated in most respects might nevertheless need to implement some similar methods. This limited similarity may not justify a hierarchical relationship. For example, you might want to add support for creating XML representations of objects in your application and for initializing objects from an XML representation:

```
- (NSXMLElement *)XMLRepresentation;  
- initWithXMLRepresentation:(NSXMLElement *)xmlString;
```

These methods could be grouped into a protocol and the similarity between implementing classes accounted for by noting that they all conform to the same protocol.

Objects can be typed by this similarity (the protocols they conform to), rather than by their class. For example, an `NSMatrix` instance must communicate with the objects that represent its cells. The matrix could require each of these objects to be a kind of `NSCell` (a type based on class) and rely on the fact that all objects that inherit from the `NSCell` class have the methods needed to respond to `NSMatrix` messages. Alternatively,

the `NSMatrix` object could require objects representing cells to have methods that can respond to a particular set of messages (a type based on protocol). In this case, the `NSMatrix` object wouldn't care what class a cell object belonged to, just that it implemented the methods.

Formal Protocols

The Objective-C language provides a way to formally declare a list of methods (including declared properties) as a protocol. **Formal protocols** are supported by the language and the runtime system. For example, the compiler can check for types based on protocols, and objects can introspect at runtime to report whether or not they conform to a protocol.

Declaring a Protocol

You declare formal protocols with the `@protocol` directive:

```
@protocol ProtocolName
method declarations
@end
```

For example, you could declare an XML representation protocol like this:

```
@protocol MyXMLSupport
- initWithXMLRepresentation:(NSXMLElement *)XMLElement;
- (NSXMLElement *)XMLRepresentation;
@end
```

Unlike class names, protocol names don't have global visibility. They live in their own namespace.

Optional Protocol Methods

Protocol methods can be marked as optional using the `@optional` keyword. Corresponding to the `@optional` modal keyword, there is a `@required` keyword to formally denote the semantics of the default behavior. You can use `@optional` and `@required` to partition your protocol into sections as you see fit. If you do not specify any keyword, the default is `@required`.

```
@protocol MyProtocol
```

```
- (void)requiredMethod;

@optional
- (void)anOptionalMethod;
- (void)anotherOptionalMethod;

@required
- (void)anotherRequiredMethod;

@end
```

Note In Mac OS X v10.5, protocols cannot include optional declared properties. This constraint is removed in Mac OS X v10.6 and later.

Informal Protocols

In addition to formal protocols, you can also define an **informal protocol** by grouping the methods in a category declaration:

```
@interface NSObject ( MyXMLSupport )
- initWithXMLRepresentation:(NSXMLElement *)XMLElement;
- (NSXMLElement *)XMLRepresentation;
@end
```

Informal protocols are typically declared as categories of the `NSObject` class, because that broadly associates the method names with any class that inherits from `NSObject`. Because all classes inherit from the root class, the methods aren't restricted to any part of the **inheritance hierarchy**. (It is also possible to declare an informal protocol as a category of another class to limit it to a certain branch of the inheritance hierarchy, but there is little reason to do so.)

When used to declare a protocol, a category interface doesn't have a corresponding implementation. Instead, classes that implement the protocol declare the methods again in their own interface files and define them along with other methods in their **implementation** files.

An informal protocol bends the rules of category declarations to list a group of methods but not associate them with any particular class or implementation.

Being informal, protocols declared in categories don't receive much language support. There's no type checking at compile time nor a check at runtime to see whether an object conforms to the protocol. To get these benefits, you must use a formal protocol. An informal protocol may be useful when all the methods are optional, such as for a **delegate**, but (in Mac OS X v10.5 and later) it is typically better to use a formal protocol with optional methods.

Protocol Objects

Just as classes are represented at runtime by class objects and methods by selector codes, formal protocols are represented by a special data type—instances of the `Protocol` class. Source code that deals with a protocol (other than to use it in a type specification) must refer to the corresponding protocol object.

In many ways, protocols are similar to class definitions. They both declare methods, and at runtime they're both represented by objects—classes by instances of `Class` and protocols by instances of `Protocol`. Like class objects, protocol objects are created automatically from the definitions and declarations found in source code and are used by the runtime system. They're not allocated and initialized in program source code.

Source code can refer to a protocol object using the `@protocol()` directive—the same directive that declares a protocol, except that here it has a set of trailing parentheses. The parentheses enclose the protocol name:

```
Protocol *myXMLSupportProtocol = @protocol(MyXMLSupport);
```

This is the only way that source code can conjure up a protocol object. Unlike a class name, a protocol name doesn't designate the object—except inside `@protocol()`.

The compiler creates a protocol object for each protocol declaration it encounters, but only if the protocol is also:

- Adopted by a class, or
- Referred to somewhere in source code (using `@protocol()`)

Protocols that are declared but not used (except for type checking as described below) aren't represented by protocol objects at runtime.

Adopting a Protocol

Adopting a protocol is similar in some ways to declaring a superclass. Both assign methods to the class. The superclass declaration assigns it inherited methods; the protocol assigns it methods declared in the protocol list. A class is said to **adopt** a formal protocol if in its declaration it lists the protocol within angle brackets after the superclass name:

```
@interface ClassName : ItsSuperclass < protocol list >
```

Categories adopt protocols in much the same way:

```
@interface ClassName ( CategoryName ) < protocol list >
```

A class can adopt more than one protocol; names in the protocol list are separated by commas.

```
@interface Formatter : NSObject < Formatting, Prettifying >
```

A class or category that adopts a protocol must implement all the required methods the protocol declares, otherwise the compiler issues a warning. The `Formatter` class above would define all the required methods declared in the two protocols it adopts, in addition to any it might have declared itself.

A class or category that adopts a protocol must import the header file where the protocol is declared. The methods declared in the adopted protocol are not declared elsewhere in the class or category interface.

It's possible for a class to simply adopt protocols and declare no other methods. For example, the following class declaration adopts the `Formatting` and `Prettifying` protocols, but declares no instance variables or methods of its own:

```
@interface Formatter : NSObject < Formatting, Prettifying >  
@end
```

Conforming to a Protocol

A class is said to **conform** to a formal protocol if it adopts the protocol or inherits from another class that adopts it. An instance of a class is said to conform to the same set of protocols its class conforms to.

Because a class must implement all the required methods declared in the protocols it adopts, saying that a class or an instance conforms to a protocol is equivalent to saying that it has in its repertoire all the methods the protocol declares.

It's possible to check whether an object conforms to a protocol by sending it a `conformsToProtocol:` message.

```
if ( ! [receiver conformsToProtocol:@protocol(MyXMLSupport)] ) {  
    // Object does not conform to MyXMLSupport protocol  
    // If you are expecting receiver to implement methods declared in the  
    // MyXMLSupport protocol, this is probably an error  
}
```

(Note that there is also a class method with the same name—`conformsToProtocol:`.)

The `conformsToProtocol:` test is like the `respondsToSelector:` test for a single method, except that it tests whether a protocol has been adopted (and presumably all the methods it declares implemented) rather than just whether one particular method has been implemented. Because it checks for all the methods in the protocol, `conformsToProtocol:` can be more efficient than `respondsToSelector:`.

The `conformsToProtocol:` test is also like the `isKindOfClass:` test, except that it tests for a type based on a protocol rather than a type based on the inheritance hierarchy.

Type Checking

Type declarations for objects can be extended to include formal protocols. Protocols thus offer the possibility of another level of type checking by the compiler, one that's more abstract since it's not tied to particular implementations.

In a type declaration, protocol names are listed between angle brackets after the type name:

```
- (id <Formatting>)formattingService;  
id <MyXMLSupport> anObject;
```

Just as static typing permits the compiler to test for a type based on the class hierarchy, this syntax permits the compiler to test for a type based on conformance to a protocol.

For example, if `Formatter` is an abstract class, the declaration

```
Formatter *anObject;
```

groups all objects that inherit from `Formatter` into a type and permits the compiler to check assignments against that type.

Similarly, the declaration

```
id <Formatting> anObject;
```

groups all objects that conform to the `Formatting` protocol into a type, regardless of their positions in the class hierarchy. The compiler can make sure only objects that conform to the protocol are assigned to the type.

In each case, the type groups similar objects—either because they share a common inheritance, or because they converge on a common set of methods.

The two types can be combined in a single declaration:

```
Formatter <Formatting> *anObject;
```

Protocols can't be used to type class objects. Only instances can be statically typed to a protocol, just as only instances can be statically typed to a class. (However, at runtime, both classes and instances respond to a `conformsToProtocol:` message.)

Protocols Within Protocols

One protocol can incorporate other protocols using the same syntax that classes use to adopt a protocol:

```
@protocol ProtocolName < protocol list >
```

All the protocols listed between angle brackets are considered part of the *ProtocolName* protocol. For example, if the `Paging` protocol incorporates the `Formatting` protocol

```
@protocol Paging < Formatting >
```

any object that conforms to the `Paging` protocol also conforms to `Formatting`. Type declarations such as

```
id <Paging> someObject;
```

and `conformsToProtocol:` messages such as

```
if ( [anotherObject conformsToProtocol:@protocol(Paging)] )  
    ...
```

need to mention only the `Paging` protocol to test for conformance to `Formatting` as well.

When a class adopts a protocol, it must implement the required methods the protocol declares, as mentioned earlier. In addition, it must conform to any protocols the adopted protocol incorporates. If an incorporated protocol incorporates still other protocols, the class must also conform to them. A class can conform to an incorporated protocol using either of these techniques:

- Implementing the methods the protocol declares
- Inheriting from a class that adopts the protocol and implements the methods

Suppose, for example, that the `Pager` class adopts the `Paging` protocol. If `Pager` is a subclass of `NSObject` as shown here:

```
@interface Pager : NSObject < Paging >
```

it must implement all the `Paging` methods, including those declared in the incorporated `Formatting` protocol. It adopts the `Formatting` protocol along with `Paging`.

On the other hand, if `Pager` is a subclass of `Formatter` (a class that independently adopts the `Formatting` protocol) as shown here:

```
@interface Pager : Formatter < Paging >
```

it must implement all the methods declared in the `Paging` protocol proper, but not those declared in `Formatting`. `Pager` inherits conformance to the `Formatting` protocol from `Formatter`.

Note that a class can conform to a protocol without formally adopting it, simply by implementing the methods declared in the protocol.

Referring to Other Protocols

When working on complex applications, you occasionally find yourself writing code that looks like this:

```
#import "B.h"
```

```
@protocol A
- foo:(id <B>)anObject;
@end
```

where protocol B is declared like this:

```
#import "A.h"

@protocol B
- bar:(id <A>)anObject;
@end
```

In such a situation, circularity results and neither file will compile correctly. To break this recursive cycle, you must use the `@protocol` directive to make a forward reference to the needed protocol instead of importing the interface file where the protocol is defined:

```
@protocol B;

@protocol A
- foo:(id <B>)anObject;
@end
```

Note that using the `@protocol` directive in this manner simply informs the compiler that B is a protocol to be defined later. It doesn't import the interface file where protocol B is defined.

Declared Properties

The Objective-C declared properties feature provides a simple way to declare and implement an object's accessor methods.

Overview

You typically access an object's properties (in the sense of its attributes and relationships) through a pair of accessor (getter/setter) methods. By using accessor methods, you adhere to the principle of **encapsulation** (see “Mechanisms Of Abstraction” in *Object-Oriented Programming with Objective-C*). You can exercise tight control of the behavior of the getter/setter pair and the underlying state management while clients of the API remain insulated from the implementation changes.

Although using accessor methods therefore has significant advantages, writing accessor methods is a tedious process. Moreover, aspects of the property that may be important to consumers of the API are left obscured—such as whether the accessor methods are thread-safe or whether new values are copied when set.

Declared properties address these issues by providing the following features:

- The property declaration provides a clear, explicit specification of how the accessor methods behave.
- The compiler can synthesize accessor methods for you, according to the specification you provide in the declaration.
- Properties are represented syntactically as identifiers and are scoped, so the compiler can detect use of undeclared properties.

Property Declaration and Implementation

There are two parts to a declared property, its declaration and its implementation.

Property Declaration

A property declaration begins with the keyword `@property`. `@property` can appear anywhere in the method declaration list found in the `@interface` block of a class. `@property` can also appear in the declaration of a protocol or category.

```
@property (attributes) type name;
```

The `@property` directive declares a property. An optional parenthesized set of attributes provides additional details about the storage semantics and other behaviors of the property—see [“Property Declaration Attributes”](#) (page 64) for possible values. Like any other Objective-C type, each property has a type specification and a name.

Listing 4-1 illustrates the declaration of a simple property.

Listing 4-1 Declaring a simple property

```
@interface MyClass : NSObject
@property float value;
@end
```

You can think of a property declaration as being equivalent to declaring two accessor methods. Thus

```
@property float value;
```

is equivalent to:

```
- (float)value;
- (void)setValue:(float)newValue;
```

A property declaration, however, provides additional information about how the accessor methods are implemented (as described in [“Property Declaration Attributes”](#) (page 64)).

You can also put property declarations in class extensions (see [“Extensions”](#) (page 74)). For example, you could declare the `value` property shown previously as follows:

```
@interface MyClass : NSObject
@end
```

```
@interface MyClass ()  
@property float value;  
@end
```

This is useful if you want to hide the declaration of private properties.

Property Declaration Attributes

You can decorate a property with attributes by using the form `@property(attribute [, attribute2, . . .])`. Like methods, properties are scoped to their enclosing interface declaration. For property declarations that use a comma-delimited list of variable names, the property attributes apply to all of the named properties.

If you use the `@synthesize` directive to tell the compiler to create the accessor methods (see [“Property Implementation Directives”](#) (page 67)), the code it generates matches the specification given by the keywords. If you implement the accessor methods yourself, you should ensure that it matches the specification (for example, if you specify `copy` you must make sure that you do copy the input value in the setter method).

Accessor Method Names

The default names for the getter and setter methods associated with a property are *propertyName* and *setPropertyName*: respectively—for example, given a property “foo”, the accessors would be `foo` and `setFoo`. The following attributes allow you to specify custom names instead. They are both optional and can appear with any other attribute (except for `readonly` in the case of `setter=`).

`getter=getterName`

Specifies the name of the get accessor for the property. The getter must return a type matching the property’s type and take no parameters.

`setter=setterName`

Specifies the name of the set accessor for the property. The setter method must take a single parameter of a type matching the property’s type and must return `void`.

If you specify that a property is `readonly` and also specify a setter with `setter=`, you get a compiler warning.

Typically you should specify accessor method names that are key-value coding compliant (see *Key-Value Coding Programming Guide*)—a common reason for using the `getter` decorator is to adhere to the *isPropertyName* convention for Boolean values.

Writability

These attributes specify whether or not a property has an associated set accessor. They are mutually exclusive.

`readwrite`

Indicates that the property should be treated as read/write. This attribute is the default.

Both a getter and setter method are required in the `@implementation` block. If you use the `@synthesize` directive in the implementation block, the getter and setter methods are synthesized.

`readonly`

Indicates that the property is read-only.

If you specify `readonly`, only a getter method is required in the `@implementation` block. If you use the `@synthesize` directive in the implementation block, only the getter method is synthesized. Moreover, if you attempt to assign a value using the dot syntax, you get a compiler error.

Setter Semantics

These attributes specify the semantics of a set accessor. They are mutually exclusive.

`strong`

Specifies that there is a strong (owning) relationship to the destination object.

`weak`

Specifies that there is a weak (non-owning) relationship to the destination object.

If the destination object is deallocated, the property value is automatically set to `nil`.

(Weak properties are not supported on OS X v10.6 and iOS 4; use `assign` instead.)

`copy`

Specifies that a copy of the object should be used for assignment.

The previous value is sent a `release` message.

The copy is made by invoking the `copy` method. This attribute is valid only for object types, which must implement the `NSCopying` protocol.

`assign`

Specifies that the setter uses simple assignment. This attribute is the default.

You use this attribute for scalar types such as `NSInteger` and `CGRect`.

`retain`

Specifies that `retain` should be invoked on the object upon assignment.

The previous value is sent a `release` message.

In OS X v10.6 and later, you can use the `__attribute__` keyword to specify that a Core Foundation property should be treated like an Objective-C object for memory management:

```
@property(retain) __attribute__((NSObject)) NSDictionaryRef myDictionary;
```

Atomicity

You can use this attribute to specify that accessor methods are not atomic. (There is no keyword to denote atomic.)

`nonatomic`

Specifies that accessors are nonatomic. *By default, accessors are atomic.*

Properties are atomic by default so that synthesized accessors provide robust access to properties in a multithreaded environment—that is, the value returned from the getter or set via the setter is always fully retrieved or set regardless of what other threads are executing concurrently.

If you specify `strong`, `copy`, or `retain` and do not specify `nonatomic`, then in a reference-counted environment, a synthesized get accessor for an object property uses a lock and retains and autoreleases the returned value—the implementation will be similar to the following:

```
[_internal lock]; // lock using an object-level lock
id result = [[value retain] autorelease];
[_internal unlock];
return result;
```

If you specify `nonatomic`, a synthesized accessor for an object property simply returns the value directly.

Markup and Deprecation

Properties support the full range of C-style decorators. Properties can be deprecated and support `__attribute__` style markup:

```
@property CGFloat x
AVAILABLE_MAC_OS_X_VERSION_10_1_AND_LATER_BUT_DEPRECATED_IN_MAC_OS_X_VERSION_10_4;
@property CGFloat y __attribute__((...));
```

If you want to specify that a property is an outlet (see `outlet` in iOS, and `outlet` in OS X), you use the `IBOutlet` identifier:

```
@property (nonatomic, weak) IBOutlet NSButton *myButton;
```

`IBOutlet` is not, though, a formal part of the list of attributes. For more about declaring outlet properties, see “Nib Files”.

Property Implementation Directives

You can use the `@synthesize` and `@dynamic` directives in `@implementation` blocks to trigger specific compiler actions. Note that neither is *required* for any given `@property` declaration.

Important If you do not specify either `@synthesize` or `@dynamic` for a particular property, you must provide a getter and setter (or just a getter in the case of a `readonly` property) method implementation for that property. If you do not, the compiler generates a warning.

`@synthesize`

You use the `@synthesize` directive to tell the compiler that it should synthesize the setter and/or getter methods for a property if you do not supply them within the `@implementation` block. The `@synthesize` directive also synthesizes an appropriate instance variable if it is not otherwise declared.

Listing 4-2 Using `@synthesize`

```
@interface MyClass : NSObject
@property(copy, readonly) NSString *value;
@end

@implementation MyClass
@synthesize value;
@end
```

You can use the form `property=ivar` to indicate that a particular instance variable should be used for the property, for example:

```
@synthesize firstName, lastName, age=yearsOld;
```

This specifies that the accessor methods for `firstName`, `lastName`, and `age` should be synthesized and that the property `age` is represented by the instance variable `yearsOld`. Other aspects of the synthesized methods are determined by the optional attributes (see [“Property Declaration Attributes”](#) (page 64)).

Whether or not you specify the name of the instance variable, the `@synthesize` directive can use an instance variable only from the current class, not a superclass.

There are differences in the behavior of accessor synthesis that depend on the runtime (see also [“Runtime Difference”](#) (page 71)):

- For the legacy runtimes, instance variables must already be declared in the `@interface` block of the current class. If an instance variable of the same name as the property exists, and if its type is compatible with the property’s type, it is used—otherwise, you get a compiler error.
- For the modern runtimes (see [“Runtime Versions and Platforms”](#) in *Objective-C Runtime Programming Guide*), instance variables are synthesized as needed. If an instance variable of the same name already exists, it is used.

`@dynamic`

You use the `@dynamic` keyword to tell the compiler that you will fulfill the API contract implied by a property either by providing method implementations directly or at runtime using other mechanisms such as dynamic loading of code or dynamic method resolution. It suppresses the warnings that the compiler would otherwise generate if it can’t find suitable implementations. You should use it only if you know that the methods will be available at runtime.

The example shown in Listing 4-3 illustrates using `@dynamic` with a subclass of `NSManagedObject`.

Listing 4-3 Using `@dynamic` with `NSManagedObject`

```
@interface MyClass : NSManagedObject
@property(nonatomic, retain) NSString *value;
@end

@implementation MyClass
@dynamic value;
@end
```

`NSManagedObject` is provided by the Core Data framework. A managed object class has a corresponding schema that defines attributes and relationships for the class; at runtime, the Core Data framework

generates accessor methods for these as necessary. You therefore typically declare properties for the attributes and relationships, but you don't have to implement the accessor methods yourself and shouldn't ask the compiler to do so. If you just declared the property without providing any implementation, however, the compiler would generate a warning. Using `@dynamic` suppresses the warning.

Using Properties

Supported Types

You can declare a property for any Objective-C class, Core Foundation data type, or “plain old data” (POD) type (see [C++ Language Note: POD Types](#)). For constraints on using Core Foundation types, however, see “[Core Foundation](#)” (page 70).

Property Redeclaration

You can redeclare a property in a subclass, but (with the exception of `readonly` versus `readwrite`) you must repeat its attributes in whole in the subclasses. The same holds true for a property declared in a category or protocol—while the property may be redeclared in a category or protocol, the property's attributes must be repeated in whole.

If you declare a property in one class as `readonly`, you can redeclare it as `readwrite` in a class extension (see “[Extensions](#)” (page 74)), in a protocol, or in a subclass (see “[Subclassing with Properties](#)” (page 70)). In the case of a class extension redeclaration, the fact that the property was redeclared prior to any `@synthesize` statement causes the setter to be synthesized. The ability to redeclare a read-only property as read/write enables two common implementation patterns: a mutable subclass of an immutable class (`NSString`, `NSArray`, and `NSDictionary` are all examples) and a property that has a public API that is `readonly` but a private `readwrite` implementation internal to the class. The following example shows using a class extension to provide a property that is declared as read-only in the public header but is redeclared privately as read/write.

```
// public header file
@interface MyObject : NSObject
@property (readonly, copy) NSString *language;
@end

// private implementation file
@interface MyObject ()
@property (readwrite, copy) NSString *language;
```

```
@end

@implementation MyObject
@synthesize language;
@end
```

Core Foundation

As noted in [“Property Declaration Attributes”](#) (page 64), prior to Mac OS X v10.6 you cannot specify the `retain` attribute for non-object types. If, therefore, you declare a property whose type is a CType and synthesize the accessors as illustrated in the following example:

```
@interface MyClass : NSObject
@property(readwrite) CGImageRef myImage;
@end

@implementation MyClass
@synthesize myImage;
@end
```

then in a reference-counted environment, the synthesized set accessor simply assigns the new value to the instance variable (the new value is not retained and the old value is not released). Simple assignment is typically incorrect for Core Foundation objects; you should not synthesize the methods but rather implement them yourself.

Subclassing with Properties

You can override a `readonly` property to make it writable. For example, you could define a class `MyInteger` with a `readonly` property, `value`:

```
@interface MyInteger : NSObject
@property(readonly) NSInteger value;
@end

@implementation MyInteger
```

```
@synthesize value;  
@end
```

You could then implement a subclass, `MyMutableInteger`, which redefines the property to make it writable:

```
@interface MyMutableInteger : MyInteger  
@property(readwrite) NSInteger value;  
@end  
  
@implementation MyMutableInteger  
@dynamic value;  
  
- (void)setValue:(NSInteger)newX {  
    value = newX;  
}  
@end
```

Runtime Difference

In general the behavior of properties is identical on both modern and legacy runtimes (see “Runtime Versions and Platforms” in *Objective-C Runtime Programming Guide*). There is one key difference: the modern runtime supports instance variable synthesis whereas the legacy runtime does not.

For `@synthesize` to work in the legacy runtime, you must either provide an instance variable with the same name and compatible type of the property or specify another existing instance variable in the `@synthesize` statement. With the modern runtime, if you do not provide an instance variable, the compiler adds one for you. For example, given the following class declaration and implementation:

```
@interface MyClass : NSObject  
@property float noDeclaredIvar;  
@end  
  
@implementation MyClass  
@synthesize noDeclaredIvar;  
@end
```

the compiler for the legacy runtime would generate an error at `@synthesize noDeclaredIvar;` whereas the compiler for the modern runtime would add an instance variable to represent `noDeclaredIvar`.

Categories and Extensions

A **category** allows you to add methods to an existing class—even to one for which you do not have the source. Categories are a powerful feature that allows you to extend the functionality of existing classes without subclassing. Using categories, you can also distribute the implementation of your own classes among several files. **Class extensions** are similar, but allow additional *required* APIs to be declared for a class in locations other than within the primary class `@interface` block.

Adding Methods to Classes

You can add methods to a class by declaring them in an interface file under a category name and defining them in an implementation file under the same name. The category name indicates that the methods are additions to a class declared elsewhere, not a new class. You cannot, however, use a category to add additional instance variables to a class.

The methods the category adds become part of the class type. For example, methods added to the `NSArray` class in a category are included as methods the compiler expects an `NSArray` instance to have in its repertoire. Methods added to the `NSArray` class in a subclass, however, are not included in the `NSArray` type. (This matters only for statically typed objects because static typing is the only way the compiler can know an object's class.)

Category methods can do anything that methods defined in the class proper can do. At runtime, there's no difference. The methods the category adds to the class are inherited by all the class's subclasses, just like other methods.

The declaration of a category interface looks very much like a class interface declaration—except the category name is listed within parentheses after the class name and the superclass isn't mentioned. Unless its methods don't access any instance variables of the class, the category must import the interface file for the class it extends:

```
#import "ClassName.h"

@interface ClassName ( CategoryName )
// method declarations
@end
```

Note that a category can't declare additional instance variables for the class; it includes only methods. However, all instance variables within the scope of the class are also within the scope of the category. That includes all instance variables declared by the class, even ones declared `@private`.

There's no limit to the number of categories that you can add to a class, but each category name must be different, and each should declare and define a different set of methods.

Extensions

Class extensions are like anonymous categories, except that the methods they declare must be implemented in the main `@implementation` block for the corresponding class. Using the Clang/LLVM 2.0 compiler, you can also declare properties and instance variables in a class extension.

A common use for class extensions is to redeclare property that is publicly declared as read-only privately as readwrite:

```
@interface MyClass : NSObject
@property (retain, readonly) float value;
@end

// Private extension, typically hidden in the main implementation file.
@interface MyClass ()
@property (retain, readwrite) float value;
@end
```

Notice that (in contrast to a category) no name is given in the parentheses in the second `@interface` block.

It is also generally common for a class to have a publicly declared API and to then have additional methods declared privately for use solely by the class or the framework within which the class resides. Class extensions allow you to declare additional *required* methods for a class in locations other than within the primary class `@interface` block, as illustrated in the following example:

```
@interface MyClass : NSObject
- (float)value;
@end
```

```
@interface MyClass () {  
    float value;  
}  
- (void)setValue:(float)newValue;  
@end  
  
@implementation MyClass  
  
- (float)value {  
    return value;  
}  
  
- (void)setValue:(float)newValue {  
    value = newValue;  
}  
  
@end
```

The implementation of the `setValue:` method *must* appear within the main `@implementation` block for the class (you cannot implement it in a category). If this is not the case, the compiler emits a warning that it cannot find a method definition for `setValue:`.

Associative References

Associative references, available starting in Mac OS X v10.6, simulate the addition of object instance variables to an existing class. Using associative references, you can add storage to an object without modifying the class declaration. This may be useful if you do not have access to the source code for the class, or if for binary-compatibility reasons you cannot alter the layout of the object.

Associations are based on a key. For any object you can add as many associations as you want, each using a different key. An association can also ensure that the associated object remains valid for at least the lifetime of the source object.

Creating Associations

You use the Objective-C runtime function `objc_setAssociatedObject` to make an association between one object and another. The function takes four parameters: the source object, a key, the value, and an association policy constant. Of these, the key and the association policy merit further discussion.

- The key is a `void` pointer. The key for each association must be unique. A typical pattern is to use a `static` variable.
- The policy specifies whether the associated object is assigned, retained, or copied, and whether the association is made atomically or non-atomically. This pattern is similar to that of the attributes of a declared property (see [“Property Declaration Attributes”](#) (page 64)). You specify the policy for the relationship using a constant (see `objc_AssociationPolicy` and [Associative Object Behaviors](#)).

Listing 6-1 shows how you can establish an association between an array and a string.

Listing 6-1 Establishing an association between an array and a string

```
static char overviewKey;

NSArray *array =
    [[NSArray alloc] initWithObjects:@"One", @"Two", @"Three", nil];
// For the purposes of illustration, use initWithFormat: to ensure
// the string can be deallocated
```

```
NSString *overview =
    [[NSString alloc] initWithFormat:@"%@", @"First three numbers"];

objc_setAssociatedObject (
    array,
    &overviewKey,
    overview,
    OBJC_ASSOCIATION_RETAIN
);

[overview release];
// (1) overview valid
[array release];
// (2) overview invalid
```

At point 1, the string `overview` is still valid because the `OBJC_ASSOCIATION_RETAIN` policy specifies that the array retains the associated object. When the array is deallocated, however (at point 2), `overview` is released and so in this case also deallocated. If you try to, for example, log the value of `overview`, you generate a runtime exception.

Retrieving Associated Objects

You retrieve an associated object using the Objective-C runtime function `objc_getAssociatedObject`. Continuing the example shown in [Listing 6-1](#) (page 76), you could retrieve the overview from the array using the following line of code:

```
NSString *associatedObject =
    (NSString *)objc_getAssociatedObject(array, &overviewKey);
```

Breaking Associations

To break an association, you typically call `objc_setAssociatedObject`, passing `nil` as the value.

Continuing the example shown in [Listing 6-1](#) (page 76), you could break the association between the array and the string `overview` using the following line of code:

```
objc_setAssociatedObject(array, &overviewKey, nil, OBJC_ASSOCIATION_ASSIGN);
```

Given that the associated object is being set to `nil`, the policy isn't actually important.

To break *all* associations for an object, you can call `objc_removeAssociatedObjects`. In general, however, you are discouraged from using this function because it breaks all associations for all clients. Use this function only if you need to restore an object to "pristine condition."

Complete Example

The following program combines code from the preceding sections.

```
#import <Foundation/Foundation.h>
#import <objc/runtime.h>

int main (int argc, const char * argv[]) {

    @autoreleasepool {
        static char overviewKey;

        NSArray *array = [NSArray alloc]
            initWithObjects:@ "One", @"Two", @"Three", nil];
        // For the purposes of illustration, use initWithFormat: to ensure
        // we get a deallocatable string
        NSString *overview = [NSString alloc]
            initWithFormat:@"%s", @"First three numbers"];

        objc_setAssociatedObject (
            array,
            &overviewKey,
            overview,
            OBJC_ASSOCIATION_RETAIN
        );
        [overview release];
    }
}
```

```
NSString *associatedObject =
    (NSString *) objc_getAssociatedObject (array, &overviewKey);
NSLog(@"associatedObject: %@", associatedObject);

objc_setAssociatedObject (
    array,
    &overviewKey,
    nil,
    OBJC_ASSOCIATION_ASSIGN
);
[array release];

}
return 0;
}
```

Fast Enumeration

Fast enumeration is a language feature that allows you to efficiently and safely enumerate over the contents of a collection using a concise syntax.

The for...in Syntax

The syntax for fast enumeration is defined as follows:

```
for ( Type newVariable in expression ) { statements }
```

or

```
Type existingItem;  
for ( existingItem in expression ) { statements }
```

In both cases, *expression* yields an object that conforms to the `NSFastEnumeration` protocol (see [“Adopting Fast Enumeration”](#) (page 81)). The iterating variable is set to each item in the returned object in turn, and the code defined by *statements* is executed. The iterating variable is set to `nil` when the loop ends by exhausting the source pool of objects. If the loop is terminated early, the iterating variable is left pointing to the last iteration item.

There are several advantages to using fast enumeration:

- The enumeration is considerably more efficient than, for example, using `NSEnumerator` directly.
- The syntax is concise.
- Enumeration is “safe”—the enumerator has a mutation guard so that if you attempt to modify the collection during enumeration, an exception is raised.

Because mutation of the object during iteration is forbidden, you can perform multiple enumerations concurrently.

In other respects, the feature behaves like a standard `for` loop. You can use `break` to interrupt the iteration and `continue` to advance to the next element.

Adopting Fast Enumeration

Any class whose instances provide access to a collection of other objects can adopt the `NSFastEnumeration` protocol. The collection classes in the Foundation framework—`NSArray`, `NSDictionary`, and `NSSet`—adopt this protocol, as does `NSEnumerator`. It should be obvious that in the cases of `NSArray` and `NSSet` the enumeration is over their contents. For other classes, the corresponding documentation should make clear what property is iterated over—for example, `NSDictionary` and the Core Data class `NSManagedObjectModel` provide support for fast enumeration; `NSDictionary` enumerates its keys, and `NSManagedObjectModel` enumerates its entities.

Using Fast Enumeration

The following code example illustrates using fast enumeration with `NSArray` and `NSDictionary` objects.

```
NSArray *array = [NSArray arrayWithObjects:
    @"one", @"two", @"three", @"four", nil];

for (NSString *element in array) {
    NSLog(@"element: %@", element);
}

NSDictionary *dictionary = [NSDictionary dictionaryWithObjectsAndKeys:
    @"quattuor", @"four", @"quinque", @"five", @"sex", @"six", nil];

NSString *key;
for (key in dictionary) {
    NSLog(@"English: %@, Latin: %@", key, [dictionary objectForKey:key]);
}
```

You can also use `NSEnumerator` objects with fast enumeration, as illustrated in this example:

```
NSArray *array = [NSArray arrayWithObjects:
```

```
        @"one", @"two", @"three", @"four", nil];

NSEnumerator *enumerator = [array reverseObjectEnumerator];
for (NSString *element in enumerator) {
    if ([element isEqualToString:@"three"]) {
        break;
    }
}

NSString *next = [enumerator nextObject];
// next = "two"
```

For collections or enumerators that have a well-defined order—such as an `NSArray` or an `NSEnumerator` instance derived from an array—the enumeration proceeds in that order, so simply counting iterations gives you the proper index into the collection if you need it.

```
NSArray *array = <#Get an array#>;
NSUInteger index = 0;

for (id element in array) {
    NSLog(@"Element at index %u is: %@", index, element);
    index++;
}
```

Enabling Static Behavior

This chapter explains how static typing works and discusses some other features of Objective-C, including ways to temporarily overcome its inherent dynamism.

Default Dynamic Behavior

By design, Objective-C objects are dynamic entities. As many decisions about them as possible are pushed from compile time to runtime:

- The memory for objects is **dynamically allocated** at runtime by class methods that create new instances.
- Objects are **dynamically typed**. In source code (at compile time), any object variable can be of type `id` no matter what the object's class is. The exact class of an `id` variable (and therefore its particular methods and data structure) isn't determined until the program runs.
- Messages and methods are **dynamically bound**, as described in [“Dynamic Binding”](#) (page 17). A runtime procedure matches the method selector in the message to a method implementation that “belongs to” the receiver.

These features give object-oriented programs a great deal of flexibility and power, but there's a price to pay. In particular, the compiler can't check the exact types (classes) of `id` variables. To permit better compile-time type checking, and to make code more self-documenting, Objective-C allows objects to be statically typed with a class name rather than generically typed as `id`. Objective-C also lets you turn off some of its object-oriented features in order to shift operations from runtime back to compile time.

Note Messages are somewhat slower than function calls, typically incurring an insignificant amount of overhead compared to actual work performed. The exceptionally rare case where bypassing the dynamism of Objective-C might be warranted can be proven by use of analysis tools like Shark or Instruments.

Static Typing

If a pointer to a class name is used in place of `id` in an object declaration such as

```
Rectangle *thisObject;
```

the compiler restricts the value of the declared variable to be either an instance of the class named in the declaration or an instance of a class that inherits from the named class. In the example above, `thisObject` can be only a `Rectangle` object of some kind.

Statically typed objects have the same internal data structures as objects declared to be of type `id`. The type doesn't affect the object; it affects only the amount of information given to the compiler about the object and the amount of information available to those reading the source code.

Static typing also doesn't affect how the object is treated at runtime. Statically typed objects are dynamically allocated by the same class methods that create instances of type `id`. If `Square` is a subclass of `Rectangle`, the following code would still produce an object with all the instance variables of a `Square` object, not just those of a `Rectangle` object:

```
Rectangle *thisObject = [[Square alloc] init];
```

Messages sent to statically typed objects are dynamically bound, just as messages to objects typed `id` are. The exact type of a statically typed receiver is still determined at runtime as part of the messaging process. A `display` message sent to the `thisObject` object:

```
[thisObject display];
```

performs the version of the method defined in the `Square` class, not the one in its `Rectangle` superclass.

By giving the compiler more information about an object, static typing opens up possibilities that are absent for objects typed `id`:

- In certain situations, it allows for compile-time type checking.
- It can free objects from the restriction that identically named methods must have identical return and parameter types.
- It permits you to use the structure pointer operator to directly access an object's instance variables.

The first two possibilities are discussed in the sections that follow. The third is covered in [“Defining a Class”](#) (page 33).

Type Checking

With the additional information provided by static typing, the compiler can deliver better type-checking services in two situations:

- When a message is sent to a statically typed receiver, the compiler can make sure the receiver can respond. A warning is issued if the receiver doesn't have access to the method named in the message.
- When a statically typed object is assigned to a statically typed variable, the compiler makes sure the types are compatible. A warning is issued if they're not.

An assignment can be made without warning, provided the class of the object being assigned is identical to, or inherits from, the class of the variable receiving the assignment. The following example illustrates this:

```
Shape      *aShape;  
Rectangle *aRect;  
  
aRect = [[Rectangle alloc] init];  
aShape = aRect;
```

Here `aRect` can be assigned to `aShape` because a rectangle is a kind of shape—the `Rectangle` class inherits from `Shape`. However, if the roles of the two variables are reversed and `aShape` is assigned to `aRect`, the compiler generates a warning; not every shape is a rectangle. (For reference, see [Figure 1-2](#) (page 21), which shows the class hierarchy including `Shape` and `Rectangle`.)

There's no check when the expression on either side of the assignment operator is of type `id`. A statically typed object can be freely assigned to an `id` object, or an `id` object to a statically typed object. Because methods like `alloc` and `init` return objects of type `id`, the compiler doesn't ensure that a compatible object is returned to a statically typed variable. The following code is error-prone, but is allowed nonetheless:

```
Rectangle *aRect;  
aRect = [[Shape alloc] init];
```

Return and Parameter Types

In general, methods in different classes that have the same selector (the same name) must also share the same return and parameter types. This constraint is imposed by the compiler to allow dynamic binding. Because the class of a message receiver (and therefore class-specific details about the method it's asked to perform), can't

be known at compile time, the compiler must treat all methods with the same name alike. When it prepares information on method return and parameter types for the runtime system, it creates just one method description for each method selector.

However, when a message is sent to a statically typed object, the class of the receiver is known by the compiler. The compiler has access to class-specific information about the methods. Therefore, the message is freed from the restrictions on its return and parameter types.

Static Typing to an Inherited Class

An instance can be statically typed to its own class or to any class that it inherits from. All instances, for example, can be statically typed as `NSObject`.

However, the compiler understands the class of a statically typed object only from the class name in the type designation, and it does its type checking accordingly. Typing an instance to an inherited class can therefore result in discrepancies between what the compiler thinks would happen at runtime and what actually happens.

For example, if you statically type a `Rectangle` instance as `Shape` as shown here:

```
Shape *myRectangle = [[Rectangle alloc] init];
```

the compiler treats it as a `Shape` instance. If you send the object a message to perform a `Rectangle` method,

```
BOOL solid = [myRectangle isFilled];
```

the compiler complains. The `isFilled` method is defined in the `Rectangle` class, not in `Shape`.

However, if you send it a message to perform a method that the `Shape` class knows about such as

```
[myRectangle display];
```

the compiler doesn't complain, even though `Rectangle` overrides the method. At runtime, the `Rectangle` version of the method is performed.

Similarly, suppose that the `Upper` class declares a `worry` method that returns a `double` as shown here:

```
- (double)worry;
```

and the `Middle` subclass of `Upper` overrides the method and declares a new return type:

```
- (int)worry;
```

If an instance is statically typed to the `Upper` class, the compiler thinks that its `worry` method returns a `double`, and if an instance is typed to the `Middle` class, the compiler thinks that `worry` returns an `int`. Errors result if a `Middle` instance is typed to the `Upper` class: The compiler informs the runtime system that a `worry` message sent to the object returns a `double`, but at runtime it actually returns an `int` and generates an error.

Static typing can free identically named methods from the restriction that they must have identical return and parameter types, but it can do so reliably only if the methods are declared in different branches of the class hierarchy.

Selectors

In Objective-C, *selector* has two meanings. It can be used to refer simply to the name of a method when it's used in a source-code message to an object. It also, though, refers to the unique identifier that replaces the name when the source code is compiled. Compiled selectors are of type SEL. All methods with the same name have the same selector. You can use a selector to invoke a method on an object—this provides the basis for the implementation of the target-action design pattern in Cocoa.

Methods and Selectors

For efficiency, full ASCII names are not used as method selectors in compiled code. Instead, the compiler writes each method name into a table, then pairs the name with a unique identifier that represents the method at runtime. The runtime system makes sure each identifier is unique: No two selectors are the same, and all methods with the same name have the same selector.

SEL and @selector

Compiled selectors are assigned to a special type, SEL, to distinguish them from other data. Valid selectors are never 0. You must let the system assign SEL identifiers to methods; it's futile to assign them arbitrarily.

The `@selector()` directive lets you refer to the compiled selector, rather than to the full method name. Here, the selector for `setWidth:height:` is assigned to the `setWidthHeight` variable:

```
SEL setWidthHeight;  
setWidthHeight = @selector(setWidth:height:);
```

It's most efficient to assign values to SEL variables at compile time with the `@selector()` directive. However, in some cases, you may need to convert a character string to a selector at runtime. You can do this with the `NSStringFromClass` function:

```
setWidthHeight = NSStringFromClass(aBuffer);
```

Conversion in the opposite direction is also possible. The `NSStringFromSelector` function returns a method name for a selector:


```
NSString *method;  
method = NSStringFromSelector(setWidthHeight);
```

Methods and Selectors

Compiled selectors identify method names, not method implementations. The `display` method for one class, for example, has the same selector as `display` methods defined in other classes. This is essential for polymorphism and dynamic binding; it lets you send the same message to receivers belonging to different classes. If there were one selector per method implementation, a message would be no different from a function call.

A class method and an instance method with the same name are assigned the same selector. However, because of their separate domains, there's no confusion between the two. A class could define a `display` class method in addition to a `display` instance method.

Method Return and Parameter Types

The messaging routine has access to method implementations only through selectors, so it treats all methods with the same selector alike. It discovers the return type of a method, and the data types of its parameters, from the selector. Therefore, except for messages sent to statically typed receivers, dynamic binding requires all implementations of identically named methods to have the same return type and the same parameter types. (Statically typed receivers are an exception to this rule because the compiler can learn about the method implementation from the class type.)

Although identically named class methods and instance methods are represented by the same selector, they can have different parameter types and return types.

Varying the Message at Runtime

The `performSelector:`, `performSelector:withObject:`, and `performSelector:withObject:withObject:` methods, defined in the `NSObject` protocol, take SEL identifiers as their initial parameters. All three methods map directly into the messaging function. For example,

```
[friend performSelector:@selector(gossipAbout:)  
    withObject:aNeighbor];
```

is equivalent to:

```
[friend gossipAbout:aNeighbor];
```

These methods make it possible to vary a message at runtime, just as it's possible to vary the object that receives the message. Variable names can be used in both halves of a message expression:

```
id    helper = getTheReceiver();  
SEL   request = getTheSelector();  
[helper performSelector:request];
```

In this example, the receiver (`helper`) is chosen at runtime (by the fictitious `getTheReceiver` function), and the method the receiver is asked to perform (`request`) is also determined at runtime (by the equally fictitious `getTheSelector` function).

Note `performSelector:` and its companion methods return an object of type `id`. If the method that's performed returns a different type, it should be cast to the proper type. (However, casting doesn't work for all types; the method should return a pointer or a type compatible with a pointer.)

The Target-Action Design Pattern

In its treatment of user-interface controls, AppKit makes good use of the ability to vary both the receiver and the message at runtime.

`NSControl` objects are graphical devices that can be used to give instructions to an application. Most resemble real-world control devices such as buttons, switches, knobs, text fields, dials, menu items, and the like. In software, these devices stand between the application and the user. They interpret events coming from hardware devices such as the keyboard and mouse and translate them into application-specific instructions. For example, a button labeled “Find” would translate a mouse click into an instruction for the application to start searching for something.

AppKit defines a template for creating control devices and defines a few off-the-shelf devices of its own. For example, the `NSButtonCell` class defines an object that you can assign to an `NSMatrix` instance and initialize with a size, a label, a picture, a font, and a keyboard shortcut. When the user clicks the button (or uses the keyboard shortcut), the `NSButtonCell` object sends a message instructing the application to do something. To do this, an `NSButtonCell` object must be initialized not just with an image, a size, and a label, but with directions on what message to send and who to send it to. Accordingly, an `NSButtonCell` instance can be initialized for an action message (the method selector it should use in the message it sends) and a target (the object that should receive the message).

```
[myButtonCell setAction:@selector(reapTheWind:)];  
[myButtonCell setTarget:anObject];
```

When the user clicks the corresponding button, the button cell sends the message using the `NSObject` protocol method `performSelector:withObject:`. All action messages take a single parameter, the `id` of the control device sending the message.

If Objective-C didn't allow the message to be varied, all `NSButtonCell` objects would have to send the same message; the name of the method would be frozen in the `NSButtonCell` source code. Instead of simply implementing a mechanism for translating user actions into action messages, button cells and other controls would have to constrain the content of the message. Constrained messaging would make it difficult for any object to respond to more than one button cell. There would either have to be one target for each button, or the target object would have to discover which button the message came from and act accordingly. Each time you rearranged the user interface, you would also have to reimplement the method that responds to the action message. An absence of dynamic messaging would create an unnecessary complication that Objective-C happily avoids.

Avoiding Messaging Errors

If an object receives a message to perform a method that isn't in its repertoire, an error results. It's the same sort of error as calling a nonexistent function. But because messaging occurs at runtime, the error often isn't evident until the program executes.

It's relatively easy to avoid this error when the message selector is constant and the class of the receiving object is known. As you write your programs, you can make sure that the receiver is able to respond. If the receiver is statically typed, the compiler performs this test for you.

However, if the message selector or the class of the receiver varies, it may be necessary to postpone this test until runtime. The `respondsToSelector:` method, defined in the `NSObject` class, tests whether a receiver can respond to a message. It takes the method selector as a parameter and returns whether the receiver has access to a method matching the selector:

```
if ( [anObject respondsToSelector:@selector(setOrigin:)] )  
    [anObject setOrigin:0.0 :0.0];  
else  
    fprintf(stderr, "%s can't be placed\n",  
            [NSStringFromClass([anObject class]) UTF8String]);
```

The `respondsToSelector:` runtime test is especially important when you send messages to objects that you don't have control over at compile time. For example, if you write code that sends a message to an object represented by a variable that others can set, you should make sure the receiver implements a method that can respond to the message.

Note An object can also arrange to have messages it receives forwarded to other objects if it doesn't respond to them directly itself. In that case, from the caller's perspective, the object appears to handle the message directly, even though it handles the message indirectly by forwarding it to another object. See "Message Forwarding" in *Objective-C Runtime Programming Guide* for more information.

Exception Handling

The Objective-C language has an exception-handling syntax similar to that of Java and C++. By using this syntax with the `NSException`, `NSError`, or custom classes, you can add robust error-handling to your programs. This chapter provides a summary of exception syntax and handling; for more details, see *Exception Programming Topics*.

Enabling Exception-Handling

Using GNU Compiler Collection (GCC) version 3.3 and later, Objective-C provides language-level support for exception handling. To turn on support for these features, use the `-fobjc-exceptions` switch of the GNU Compiler Collection (GCC) version 3.3 and later. (Note that this switch renders the application runnable only in Mac OS X v10.3 and later because runtime support for exception handling and synchronization is not present in earlier versions of the software.)

Exception Handling

An exception is a special condition that interrupts the normal flow of program execution. There are a variety of reasons why an exception may be generated (exceptions are typically said to be *raised* or *thrown*), by hardware as well as software. Examples include arithmetical errors such as division by zero, underflow or overflow, calling undefined instructions (such as attempting to invoke an unimplemented method), and attempting to access a collection element out of bounds.

Objective-C exception support involves four compiler directives: `@try`, `@catch`, `@throw`, and `@finally`:

- Code that can potentially throw an exception is enclosed in a `@try{}` block.
- A `@catch{}` block contains exception-handling logic for exceptions thrown in a `@try{}` block. You can have multiple `@catch{}` blocks to catch different types of exception. (For a code example, see [“Catching Different Types of Exception”](#) (page 94).)
- You use the `@throw` directive to throw an exception, which is essentially an Objective-C object. You typically use an `NSException` object, but you are not required to.
- A `@finally{}` block contains code that must be executed whether an exception is thrown or not.

This example depicts a simple exception-handling algorithm:

```
Cup *cup = [[Cup alloc] init];

@try {
    [cup fill];
}
@catch (NSException *exception) {
    NSLog(@"main: Caught %@: %@", [exception name], [exception reason]);
}
@finally {
    [cup release];
}
```

Catching Different Types of Exception

To catch an exception thrown in a `@try{}` block, use one or more `@catch{}` blocks following the `@try{}` block. The `@catch{}` blocks should be ordered from most-specific to least-specific. That way you can tailor the processing of exceptions as groups, as shown in Listing 10-1.

Listing 10-1 An exception handler

```
@try {
    ...
}
@catch (CustomException *ce) {    // 1
    ...
}
@catch (NSException *ne) {        // 2
    // Perform processing necessary at this level.
    ...
}
@catch (id ue) {
    ...
}
```

```
}  
@finally {                                // 3  
    // Perform processing necessary whether an exception occurred or not.  
    ...  
}
```

The following list describes the numbered code lines:

1. Catches the most specific exception type.
2. Catches a more general exception type.
3. Performs any clean-up processing that must always be performed, whether exceptions were thrown or not.

Throwing Exceptions

To throw an exception, you must instantiate an object with the appropriate information, such as the exception name and the reason it was thrown.

```
NSError *exception = [NSError exceptionWithName: @"HotTeaException"  
                                reason: @"The tea is too hot"  
                                userInfo: nil];  
  
@throw exception;
```

Important In many environments, use of exceptions is fairly commonplace. For example, you might throw an exception to signal that a routine could not execute normally—such as when a file is missing or data could not be parsed correctly. Exceptions are resource-intensive in Objective-C. You should not use exceptions for general flow-control, or simply to signify errors. Instead you should use the return value of a method or function to indicate that an error has occurred, and provide information about the problem in an error object. For more information, see *Error Handling Programming Guide*.

Inside a `@catch{}` block, you can rethrow the caught exception using the `@throw` directive without providing an argument. Leaving out the argument in this case can help make your code more readable.

You are not limited to throwing `NSError` objects. You can throw any Objective-C object as an exception object. The `NSError` class provides methods that help in exception processing, but you can implement your own if you so desire. You can also subclass `NSError` to implement specialized types of exceptions, such as file-system exceptions or communications exceptions.

Threading

Objective-C provides support for thread synchronization and exception handling, which are explained in this chapter and in “[Exception Handling](#)” (page 93). To turn on support for these features, use the `-fobjc-exceptions` switch of the GNU Compiler Collection (GCC) version 3.3 and later.

Note Using either of these features in a program renders the application runnable only in Mac OS X v10.3 and later because runtime support for exception handling and synchronization is not present in earlier versions of the software.

Objective-C supports multithreading in applications. Therefore, two threads can try to modify the same object at the same time, a situation that can cause serious problems in a program. To protect sections of code from being executed by more than one thread at a time, Objective-C provides the `@synchronized()` directive.

The `@synchronized()` directive locks a section of code for use by a single thread. Other threads are blocked until the thread exits the protected code—that is, when execution continues past the last statement in the `@synchronized()` block.

The `@synchronized()` directive takes as its only argument any Objective-C object, including `self`. This object is known as a *mutual exclusion semaphore* or **mutex**. It allows a thread to lock a section of code to prevent its use by other threads. You should use separate semaphores to protect different critical sections of a program. It's safest to create all the mutual exclusion objects before the application becomes multithreaded, to avoid race conditions.

Listing 11-1 shows code that uses `self` as the mutex to synchronize access to the instance methods of the current object. You can take a similar approach to synchronize the class methods of the associated class, using the class object instead of `self`. In the latter case, of course, only one thread at a time is allowed to execute a class method because there is only one class object that is shared by all callers.

Listing 11-1 Locking a method using `self`

```
- (void)criticalMethod
{
    @synchronized(self) {
        // Critical code.
    }
}
```



```
        ...  
    }  
}
```

Listing 11-2 shows a general approach. Before executing a critical process, the code obtains a semaphore from the `Account` class and uses it to lock the critical section. The `Account` class could create the semaphore in its `initialize` method.

Listing 11-2 Locking a method using a custom semaphore

```
Account *account = [Account accountFromString:[accountField stringValue]];

// Get the semaphore.
id accountSemaphore = [Account semaphore];

@synchronized(accountSemaphore) {
    // Critical code.
    ...
}
```

The Objective-C synchronization feature supports recursive and reentrant code. A thread can use a single semaphore several times in a recursive manner; other threads are blocked from using it until the thread releases all the locks obtained with it; that is, every `@synchronized()` block is exited normally or through an exception.

When code in an `@synchronized()` block throws an exception, the Objective-C runtime catches the exception, releases the semaphore (so that the protected code can be executed by other threads), and rethrows the exception to the next exception handler.

Document Revision History

This table describes the changes to *The Objective-C Programming Language*.

Date	Notes
2011-10-12	Minor updates and corrections regarding current use of declared properties.
2010-12-08	Edited for content and clarity.
2010-07-13	Updated to show the revised initialization pattern.
2009-10-19	Added discussion of associative references.
2009-08-12	Corrected minor errors.
2009-05-06	Updated article on Mixing Objective-C and C++.
2009-02-04	Updated description of categories.
2008-11-19	Significant reorganization, with several sections moved to a new Runtime Guide.
2008-10-15	Corrected typographical errors.
2008-07-08	Corrected typographical errors.
2008-06-09	Made several minor bug fixes and clarifications, particularly in the "Properties" chapter.
2008-02-08	Extended the discussion of properties to include mutable objects.
2007-12-11	Corrected minor errors.
2007-10-31	Provided an example of fast enumeration for dictionaries and enhanced the description of properties.

Date	Notes
2007-07-22	Added references to documents describing new features in Objective-C 2.
2007-03-26	Corrected minor typographical errors.
2007-02-08	Clarified the discussion of sending messages to nil.
2006-12-05	Clarified the description of Code Listing 3-3.
2006-05-23	Moved the discussion of memory management to "Memory Management Programming Guide for Cocoa."
2006-04-04	Corrected minor typographical errors.
2006-02-07	Corrected minor typographical errors.
2006-01-10	Clarified use of the static specifier for global variables used by a class.
2005-10-04	Clarified effect of sending messages to nil; noted use of ".mm" extension to signal Objective-C++ to compiler.
2005-04-08	<p>Corrected typo in language grammar specification and modified a code example.</p> <p>Corrected the grammar for the protocol-declaration-list declaration in "External Declarations".</p> <p>Clarified example in "Using C++ and Objective-C instances as instance variables".</p>
2004-08-31	<p>Removed function and data structure reference. Added exception and synchronization grammar. Made technical corrections and minor editorial changes.</p> <p>Moved function and data structure reference to <i>Objective-C Runtime Reference</i>.</p> <p>Added examples of thread synchronization approaches to "Synchronizing Thread Execution".</p>

Date	Notes
	<p>Clarified when the <code>initialize</code> method is called and provided a template for its implementation in “Initializing a Class Object”.</p> <p>Added exception and synchronization grammar to “Grammar”.</p> <p>Replaced <code>conformsTo:</code> with <code>conformsToProtocol:</code> throughout document.</p>
2004-02-02	Corrected typos in “An exception handler”.
2003-09-16	Corrected definition of <code>id</code> .
2003-08-14	<p>Documented the Objective-C exception and synchronization support available in Mac OS X version 10.3 and later in “Exception Handling and Thread Synchronization”.</p> <p>Documented the language support for concatenating constant strings in “Compiler Directives”.</p> <p>Moved “Memory Management” before “Retaining Objects”.</p> <p>Corrected the descriptions for the <code>Ivar</code> structure and the <code>objc_ivar_list</code> structure.</p> <p>Changed the font of <i>function result</i> in <code>class_getInstanceMethod</code> and <code>class_getClassMethod</code>.</p> <p>Corrected definition of the term <i>conform</i> in the glossary.</p> <p>Corrected definition of <code>method_getArgumentInfo</code>.</p> <p>Renamed from <i>Inside Mac OS X: The Objective-C Programming Language</i> to <i>The Objective-C Programming Language</i>.</p>
2003-01-01	Documented the language support for declaring constant strings. Fixed several typographical errors. Added an index.
2002-05-01	Mac OS X 10.1 introduces a compiler for Objective-C++, which allows C++ constructs to be called from Objective-C classes, and vice versa.

Date	Notes
	Added runtime library reference material.
	Fixed a bug in the Objective-C language grammar's description of instance variable declarations.
	Updated grammar and section names throughout the book to reduce ambiguities, passive voice, and archaic tone. Restructured some sections to improve cohesiveness.
	Renamed from <i>Object Oriented Programming and the Objective-C Language</i> to <i>Inside Mac OS X: The Objective-C Programming Language</i> .

Glossary

abstract class A class that's defined solely so that other classes can inherit from it. Programs don't use instances of an abstract class; they use only instances of its subclasses.

abstract superclass Same as [abstract class](#).

adopt In the Objective-C language, a class is said to adopt a protocol if it declares that it implements all the methods in the protocol. Protocols are adopted by listing their names between angle brackets in a class or category declaration.

anonymous object An object of unknown class. The interface to an anonymous object is published through a protocol declaration.

AppKit Sometimes called *Application Kit*. A Cocoa framework that implements an application's user interface. AppKit provides a basic program structure for applications that draw on the screen and respond to events.

asynchronous message A remote message that returns immediately, without waiting for the application that receives the message to respond. The sending application and the receiving application act independently, and are therefore not in sync. Compare [synchronous message](#).

category In the Objective-C language, a set of method definitions that is segregated from the rest of the class definition. Categories can be used to split a class definition into parts or to add methods to an existing class.

class In the Objective-C language, a prototype for a particular kind of object. A class definition declares instance variables and defines methods for all members of the class. Objects that have the same types of instance variables and have access to the same methods belong to the same class. See also [class object](#).

class method In the Objective-C language, a method that can operate on class objects rather than instances of the class.

class object In the Objective-C language, an object that represents a class and knows how to create new instances of the class. Class objects are created by the compiler, lack instance variables, and can't be statically typed, but otherwise behave like all other objects. As the receiver in a message expression, a class object is represented by the class name.

Cocoa An advanced object-oriented development platform in Mac OS X. Cocoa is a set of frameworks whose primary programming interfaces are in Objective-C.

compile time The time when source code is compiled. Decisions made at compile time are constrained by the amount and kind of information encoded in source files.

conform In the Objective-C language, a class is said to conform to a protocol if it (or a superclass) implements the methods declared in the protocol. An instance conforms to a protocol if its class does. Thus, an instance that conforms to a protocol can perform any of the instance methods declared in the protocol.

delegate An object that acts on behalf of another object.

designated initializer The `init...` method that has primary responsibility for initializing new instances of a class. Each class defines or inherits its own designated initializer. Through messages to `self`, other `init...` methods in the same class directly or indirectly invoke the designated initializer, and the designated initializer, through a message to `super`, invokes the designated initializer of its superclass.

dispatch table The Objective-C runtime table that contains entries that associate method selectors with the class-specific addresses of the methods they identify.

distributed objects An architecture that facilitates communication between objects in different address spaces.

dynamic allocation A technique used in C-based languages where the operating system provides memory to a running application as it needs it, instead of when it launches.

dynamic binding Binding a method to a message—that is, finding the method implementation to invoke in response to the message—at runtime, rather than at compile time.

dynamic typing Discovering the class of an object at runtime rather than at compile time.

encapsulation A programming technique that hides the implementation of an operation from its users behind an abstract interface. It allows the implementation to be updated or changed without impacting the users of the interface.

event The direct or indirect report of external activity, especially user activity on the keyboard and mouse.

factory Same as [class object](#).

factory object Same as [class object](#).

formal protocol In the Objective-C language, a protocol that's declared with the `@protocol` directive. Classes can adopt formal protocols, objects can respond at runtime when asked if they conform to a formal protocol, and instances can be typed by the formal protocols they conform to.

framework A way to package a logically related set of classes, protocols, and functions together with localized strings, online documentation, and other pertinent files. Cocoa provides the Foundation framework and the AppKit framework, among others.

id In the Objective-C language, the general type for any kind of object regardless of class. `id` is defined as a pointer to an object data structure. It can be used for both class objects and instances of a class.

implementation The part of an Objective-C class specification that defines public methods (those declared in the class's interface) as well as private methods (those not declared in the class's interface).

informal protocol In the Objective-C language, a protocol declared as a category, usually as a category of the `NSObject` class. The language gives explicit support to formal protocols, but not to informal ones.

inheritance In object-oriented programming, the ability of a superclass to pass its characteristics (methods and instance variables) on to its subclasses.

inheritance hierarchy In object-oriented programming, the hierarchy of classes that's defined by the arrangement of superclasses and subclasses. Every class (except root classes such as `NSObject`) has a superclass, and any class may have an

unlimited number of subclasses. Through its superclass, each class inherits from those above it in the hierarchy.

instance In the Objective-C language, an object that belongs to (is a member of) a particular class. Instances are created at runtime according to the specification in the class definition.

instance method In the Objective-C language, any method that can be used by an instance of a class rather than by the class object.

instance variable In the Objective-C language, any variable that's part of the internal data structure of an instance. Instance variables are declared in a class definition and become part of all objects that are members of or inherit from the class.

interface The part of an Objective-C class specification that declares its public interface, which includes its superclass name, instances variables, and public-method prototypes.

Interface Builder A tool that lets you graphically specify your application's user interface. It sets up the corresponding objects for you and makes it easy for you to establish connections between these objects and your own code where needed.

link time The time when files compiled from different source modules are linked into a single program. Decisions made by the linker are constrained by the compiled code and ultimately by the information contained in source code.

message In object-oriented programming, the method selector (name) and accompanying parameters that tell the receiving object in a message expression what to do.

message expression In object-oriented programming, an expression that sends a message to an object. In the Objective-C language, message

expressions are enclosed within square brackets and consist of a receiver followed by a message (method selector and parameters).

method In object-oriented programming, a procedure that can be executed by an object.

mutex Short for *mutual exclusion semaphore*. An object used to synchronize thread execution.

namespace A logical subdivision of a program within which all names must be unique. Symbols in one namespace do not conflict with identically named symbols in another namespace. For example, in Objective-C, the instance methods of a class are in a unique namespace for the class. Similarly, the class methods of a class are in their own namespace, and the instance variables of a class are in their own namespace.

nil In the Objective-C language, an object `id` with a value of 0.

object A programming unit that groups together a data structure (instance variables) and the operations (methods) that can use or affect that data. Objects are the principal building blocks of object-oriented programs.

outlet An instance variable that points to another object. Outlet instance variables are a way for an object to keep track of the other objects to which it may need to send messages.

polymorphism In object-oriented programming, the ability of different objects to respond, each in its own way, to the same message.

procedural programming language A language, such as C, that organizes a program as a set of procedures that have definite beginnings and ends.

protocol In the Objective-C language, the declaration of a group of methods not associated with any particular class. See also [formal protocol](#), [informal protocol](#).

receiver In object-oriented programming, the object that is sent a message.

reference counting A memory-management technique in which each entity that claims ownership of an object increments the object's reference count and later decrements it. When the object's reference count reaches zero, the object is deallocated. This technique allows one instance of an object to be safely shared among several other objects.

remote message A message sent from one application to an object in another application.

remote object An object in another application, one that's a potential receiver for a remote message.

runtime The time after a program is launched and while it's running. Decisions made at runtime can be influenced by choices the user makes.

selector In the Objective-C language, the name of a method when it's used in a source-code message to an object, or the unique identifier that replaces the name when the source code is compiled. Compiled selectors are of type SEL.

static typing In the Objective-C language, giving the compiler information about what kind of object an instance is, by typing it as a pointer to a class.

subclass In the Objective-C language, any class that's one step below another class in the inheritance hierarchy. Occasionally used more generally to mean any class that inherits from another class. Also used as a verb to mean the process of defining a subclass of another class.

superclass In the Objective-C language, a class that's one step above another class in the inheritance hierarchy; the class through which a subclass inherits methods and instance variables.

synchronous message A remote message that doesn't return until the receiving application finishes responding to the message. Because the application that sends the message waits for an acknowledgment or return information from the receiving application, the two applications are kept in sync. Compare [asynchronous message](#).



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