COCOA® PROGRAMMING FOR MAC® OS X

FOURTH EDITION

AARON HILLEGASS ADAM PREBLE

Cocoa® Programming for Mac® OS X

Fourth Edition

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FOURTH EDITION

Aaron Hillegass
Adam Preble

Addison-Wesley

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For Aaron's sons, Walden and Otto

and

For Adam's daughter, Aimee

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Preface

If you are developing applications for the Mac, or are hoping to do so, this book is just the resource you need. Does it cover everything you will ever want to know about programming for the Mac? Of course not. But it does cover probably 80% of what you need to know. You can find the remaining 20%—the 20% that is unique to you—in Apple's online documentation.

This book, then, acts as a foundation. It covers the Objective-C language and the major design patterns of Cocoa. It will also get you started with the two most commonly used developer tools: Xcode and Instruments. After reading this book, you will be able to understand and utilize Apple's online documentation.

There is a lot of code in this book. Through that code, we will introduce you to the idioms of the Cocoa community. Our hope is that by presenting exemplary code, we can help you to become more than a Cocoa developer—a stylish Cocoa developer.

This fourth edition includes technologies introduced in Mac OS X 10.6 and 10.7. These include Xcode 4, ARC, blocks, view-based table views, and the Mac App Store. We have also devoted one chapter to the basics of iOS development.

This book is written for programmers who already know some C programming and something about objects. If you don't know C or objects, you should first read *Objective-C Programming: The Big Nerd Ranch Guide*. You are not expected to have any experience with Mac programming. This hands-on book assumes that you have access to Mac OS X and the developer tools. Xcode 4.2, Apple's IDE, is available for free. If you are a member of the paid Mac or iOS Developer Programs, Xcode can also be downloaded from the Apple Developer Connection Web site (http://developer.apple.com/). Enrollment in these programs enables you to submit your applications to the Mac and iOS App Stores, respectively.

We have tried to make this book as useful for you as possible, if not indispensable. That said, we'd love to hear from you at cocoabook@bignerdranch.com if you have any suggestions for improving it.

—Aaron Hillegass and Adam Preble

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Creating this book required the efforts of many people. We want to thank them for their help. Their contributions have made this a better book than we could have ever written alone.

Thanks to the students who took the Cocoa programming course at the Big Nerd Ranch. They helped us work the kinks out of the exercises and explanations that appear here. Their curiosity inspired us to make the book more comprehensive, and their patience made it possible.

Thank you to all the readers of the first three editions, who made such great suggestions on our forums (http://forums.bignerdranch.com/).

Thank you to all the instructors at the Ranch, who made great additions and caught many of our most egregious errors.

A final shout out to the people at Addison-Wesley, who took our manuscript and made it into a book. They put the book on trucks and convinced bookstores to put it on the shelves. Without their help, it would still be just a stack of paper.

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Chapter 3
OBJECTIVE-C

Once upon a time, a man named Brad Cox decided that it was time for the world to move toward a more modular programming style. C was a popular and powerful language. Smalltalk was an elegant untyped object-oriented language. Starting with C, Brad Cox added Smalltalk-like classes and message-sending mechanisms. He called the result *Objective-C*. Objective-C is a very simple extension of the C language. In fact, it was originally just a C preprocessor and a library.

Objective-C is not a proprietary language. Rather, it is an open standard that has been included in the Free Software Foundation's GNU C compiler (gcc) for many years. More recently, Apple has become heavily involved in the clang/LLVM (Low Level Virtual Machine) open source compiler projects, which are much faster and more versatile than gcc. In Xcode projects, LLVM is the default compiler.

Cocoa was developed using Objective-C, and most Cocoa programming is done in Objective-C. Teaching C and basic object-oriented concepts could consume an entire book. This chapter assumes that you already know a little C and something about objects and introduces you to the basics of Objective-C. If you fit the profile, you will find learning Objective-C to be easy. If you do not, our own *Objective-C Programming: The Big Nerd Ranch Guide* or Apple's *The Objective-C Language* offer more gentle introductions.

Creating and Using Instances

Chapter 1 mentioned that classes are used to create objects, that the objects have methods, and that you can send messages to the objects to trigger these methods. In this section, you will learn how to create an object and send messages to it.

As an example, we will use the class **NSMutableArray**. You can create a new instance of **NSMutableArray** by sending the message **alloc** to the **NSMutableArray** class like this:

```
[NSMutableArray alloc];
```

This method returns a pointer to the space that was allocated for the object. You could hold onto that pointer in a variable like this:

```
NSMutableArray *foo;
foo = [NSMutableArray alloc];
```

While working with Objective-C, it is important to remember that `foo` is just a pointer. In this case, it points to an object.

Before using the object that `foo` points to, you would need to make sure that it is fully initialized. The **`init`** method will handle this task, so you might write code like this:

```
NSMutableArray *foo;
foo = [NSMutableArray alloc];
[foo init];
```

Take a long look at the last line; it sends the message **`init`** to the object that `foo` points to. We would say, "`foo` is the receiver of the message **`init`**." Note that a message send consists of a receiver (the object `foo` points to) and a message (**`init`**) wrapped in brackets. You can also send messages to *classes*, as demonstrated by sending the message **`alloc`** to the class **`NSMutableArray`**.

The method **`init`** returns the newly initialized object. As a consequence, you will always nest the message sends like this:

```
NSMutableArray *foo;
foo = [[NSMutableArray alloc] init];
```

What about destroying the object when we no longer need it? We will talk about this in the next chapter.

Some methods take arguments. If a method takes an argument, the method name (called a *selector*) will end with a colon. For example, to add objects to the end of the array, you use the **`addObject:`** method (assume that `bar` is a pointer to another object):

```
[foo addObject:bar];
```

If you have multiple arguments, the selector will have multiple parts. For example, to add an object at a particular index, you could use the following:

```
[foo insertObject:bar atIndex:5];
```

Note that **`insertObject:atIndex:`** is one selector, not two. It will trigger one method with two arguments. This outcome seems strange to most C and Java programmers but should be familiar to Smalltalk programmers. The syntax also makes your code easier to read. For example, it is not uncommon to see a C++ method call like this:

```
if (x.intersectsArc(35.0, 19.0, 23.0, 90.0, 120.0))
```

It is much easier to guess the meaning of the following code:

```
if ([x intersectsArcWithRadius:35.0
                  centeredAtX:19.0
                            Y:23.0
                    fromAngle:90.0
                      toAngle:120.0])
```

If it seems odd right now, just use it for a while. Most programmers grow to appreciate the Objective-C messaging syntax.

You are now at a point where you can read simple Objective-C code, so it is time to write a program that will create an instance of **`NSMutableArray`** and fill it with ten instances of **`NSNumber`**.

Using Existing Classes

If it isn't running, start Xcode. Close any projects that you were working on. Under the File menu, choose New -> New Project…. When the panel pops up, choose to create a Command Line Tool (Figure 3.1).

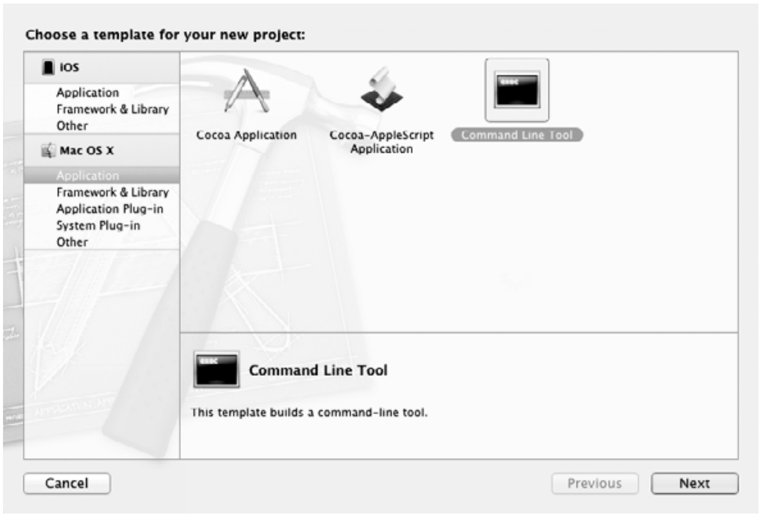
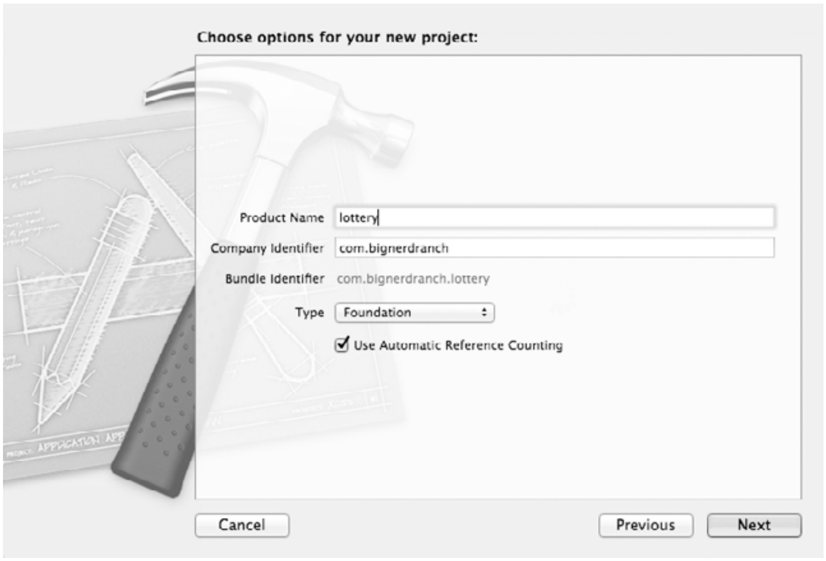


Figure 3.1 Choose Project Type

A *command-line tool* has no graphical user interface and typically runs on the command line or in the background as a daemon. Unlike in an application project, you will always alter the **main** function of a command-line tool.

Name the project lottery (Figure 3.2). Unlike the names of applications, most tool names are lowercase. Set the Type to Foundation.


Choose options for your new project:

Product Name: lottery
Company Identifier: com.bignerdranch
Bundle Identifier: com.bignerdranch.lottery
Type: Foundation
✓ Use Automatic Reference Counting

Figure 3.2 Name Project

When the new project appears, select `main.m` in the lottery group. Edit `main.m` to look like this:

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

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

        NSMutableArray *array;
        array = [[NSMutableArray alloc] init];
        int i;
        for (i = 0; i < 10; i++) {
            NSNumber *newNumber =
                       [[NSNumber alloc] initWithInt:(i * 3)];
            [array addObject:newNumber];
        }
        for ( i = 0; i < 10; i++) {
            NSNumber *numberToPrint = [array objectAtIndex:i];
            NSLog(@"The number at index %d is %@",  i, numberToPrint);
        }

    }
    return 0;
}
```

Here is the play-by-play for the code:

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

You are including the headers for all the classes in the Foundation framework. The headers are precompiled, so this approach is not as computationally intensive as it sounds.

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

The **main** function is declared just as it would be in any Unix C program.

```
@autoreleasepool {
```

This code defines an autorelease pool for the code enclosed by the braces. We will discuss the importance of autorelease pools in the next chapter.

```
NSMutableArray *array;
```

One variable is declared here: `array` is a pointer to an instance of **NSMutableArray**. Note that no array exists yet. You have simply declared a pointer that will refer to the array once it is created.

```
array = [[NSMutableArray alloc] init];
```

Here, you are creating the instance of **NSMutableArray** and making the `array` variable point to it.

```
for (i = 0; i < 10; i++) {
    NSNumber *newNumber = [[NSNumber alloc] initWithInt:(i*3)];
    [array addObject:newNumber];
}
```

Inside the `for` loop, you have created a local variable called `newNumber` and set it to point to a new instance of **NSNumber**. Then you have added that object to the array.

The array does not make copies of the **NSNumber** objects. Instead, it simply keeps a list of pointers to the **NSNumber** objects. Objective-C programmers make very few copies of objects, because it is seldom necessary.

```
for ( i = 0; i < 10; i++) {
    NSNumber *numberToPrint = [array objectAtIndex:i];
    NSLog(@"The number at index %d is %@", i, numberToPrint);
}
```

Here, you are printing the contents of the array to the console. **NSLog** is a function much like the C function **printf()**; it takes a format string and a comma-separated list of variables to be substituted into the format string. When displaying the string, **NSLog** prefixes the generated string with the name of the application and a time stamp.

In **printf**, for example, you would use %x to display an integer in hexadecimal form. With **NSLog**, we have all the tokens from **printf** and the token %@ to display an object. The object gets sent the message **description**, and the string it returns replaces %@ in the string. We will discuss the **description** method in detail soon.

All the tokens recognized by **NSLog()** are listed in Table 3.1.

Table 3.1 Possible Tokens in Objective-C Format Strings

Symbol	Displays
%@	id
%d, %D, %i	long
%u, %U	unsigned long
%hi	short
%hu	unsigned short
%qi	long long
%qu	unsigned long long
%x, %X	unsigned long printed as hexadecimal
%o, %O	unsigned long printed as octal
%f, %e, %E, %g, %G	double
%c	unsigned char as ASCII character
%C	unichar as Unicode character
%s	char * (a null-terminated C string of ASCII characters)
%S	unichar * (a null-terminated C string of Unicode characters)
%p	void * (an address printed in hexadecimal with a leading 0x)
%%	a % character

Note: If the @ symbol before the quotes in @"The number at index %d is %@" looks a little strange, remember that Objective-C is the C language with a couple of extensions. One of the extensions is that strings are instances of the class **NSString**. In C, strings are just pointers to a buffer of characters that ends in the null character. Both C strings and instances of **NSString** can be used in the same file. To differentiate between constant C strings and constant **NSString**s, you must put @ before the opening quote of a constant **NSString**.

```
// C string
char *foo;
// NSString
NSString *bar;
foo = "this is a C string";
bar = @"this is an NSString";
```

You will use mostly **NSString** in Cocoa programming. Wherever a string is needed, the classes in the frameworks expect an **NSString**. However, if you already have a bunch of C functions that expect C strings, you will find yourself using `char *` frequently.

You can convert between C strings and **NSString**s:

```
const char *foo = "Blah blah";
NSString *bar;
// Create an NSString from a C string
bar = [NSString stringWithUTF8String:foo];

// Create a C string from an NSString
foo = [bar UTF8String];
```

Because **NSString** can hold Unicode strings, you will need to deal with the multibyte characters correctly in your C strings, and this can be quite difficult and time consuming. (Besides the multibyte problem, you will have to wrestle with the fact that some languages read from right to left.) Whenever possible, you should use **NSString** instead of C strings.

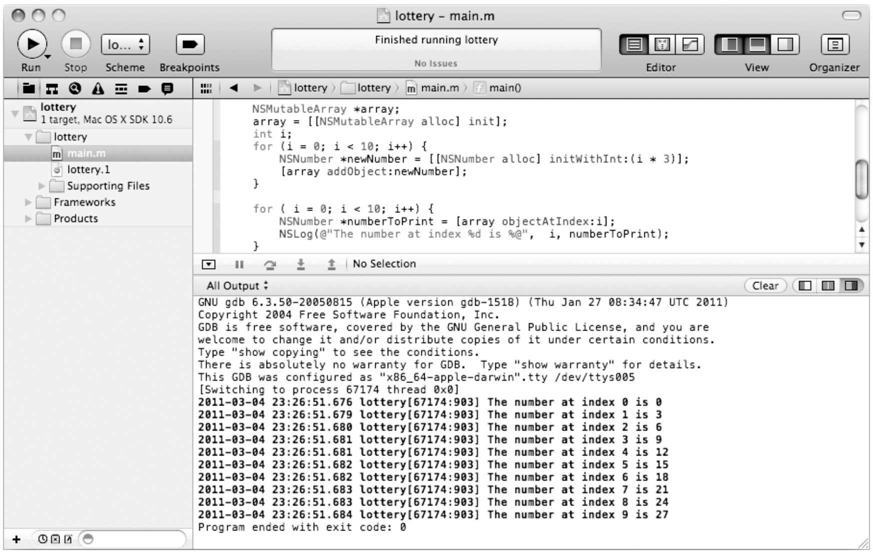
Our **main()** function ends by returning 0, indiciating that no error occurred:

```
    return 0;
}
```

Run the completed command-line tool (Figure 3.3). (If your console doesn't appear, use the View -> Show Debug Area menu item and ensure that the console, the right half, is enabled.)

Sending Messages to nil

In most object-oriented languages, your program will crash if you send a message to `null`. In applications written in those languages, you will see many



```
NSMutableArray *array;
array = [[NSMutableArray alloc] init];
int i;
for (i = 0; i < 10; i++) {
    NSNumber *newNumber = [[NSNumber alloc] initWithInt:(i * 3)];
    [array addObject:newNumber];
}

for ( i = 0; i < 10; i++) {
    NSNumber *numberToPrint = [array objectAtIndex:i];
    NSLog(@"The number at index %d is %@",  i, numberToPrint);
}
```

```
GNU gdb 6.3.50-20050815 (Apple version gdb-1518) (Thu Jan 27 08:34:47 UTC 2011)
Copyright 2004 Free Software Foundation, Inc.
GDB is free software, covered by the GNU General Public License, and you are
welcome to change it and/or distribute copies of it under certain conditions.
Type "show copying" to see the conditions.
There is absolutely no warranty for GDB.  Type "show warranty" for details.
This GDB was configured as "x86_64-apple-darwin".tty /dev/ttys005
[Switching to process 67174 thread 0x0]
2011-03-04 23:26:51.676 lottery[67174:903] The number at index 0 is 0
2011-03-04 23:26:51.679 lottery[67174:903] The number at index 1 is 3
2011-03-04 23:26:51.680 lottery[67174:903] The number at index 2 is 6
2011-03-04 23:26:51.681 lottery[67174:903] The number at index 3 is 9
2011-03-04 23:26:51.681 lottery[67174:903] The number at index 4 is 12
2011-03-04 23:26:51.682 lottery[67174:903] The number at index 5 is 15
2011-03-04 23:26:51.682 lottery[67174:903] The number at index 6 is 18
2011-03-04 23:26:51.683 lottery[67174:903] The number at index 7 is 21
2011-03-04 23:26:51.683 lottery[67174:903] The number at index 8 is 24
2011-03-04 23:26:51.684 lottery[67174:903] The number at index 9 is 27
Program ended with exit code: 0
```

Figure 3.3 Completed Execution

checks for `null` before sending a message. In Java, for example, you frequently see the following:

```
if (foo != null) {
    foo.doThatThingYouDo();
}
```

In Objective-C, it is okay to send a message to `nil`. The message is simply discarded, which eliminates the need for these sorts of checks. For example, this code will build and run without an error:

```
id foo;
foo = nil;
int bar = [foo count];
```

This approach is different from how most languages work, but you will get used to it.

You may find yourself asking over and over, "Argg! Why isn't this method getting called?" Chances are that the pointer you are using, convinced that it is not `nil`, is in fact `nil`.

In the preceding example, what is `bar` set to? Zero. If `bar` were a pointer, it would be set to `nil` (`zero` for pointers). For other types, the value is less predictable.

NSObject, NSArray, NSMutableArray, and NSString

You have now used these standard Cocoa objects: **`NSObject`**, **`NSMutableArray`**, and **`NSString`**. (All classes that come with Cocoa have names with the `NS` prefix. Classes that you will create will *not* start with `NS`.) These classes are all part of the Foundation framework. Figure 3.4 shows an inheritance diagram for these classes.

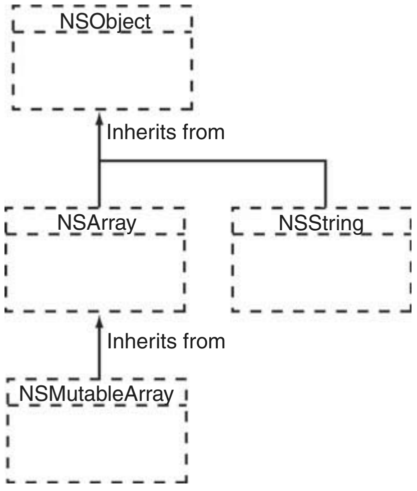


Figure 3.4 Inheritance Diagram

Let's go through a few of the commonly used methods on these classes. For a complete listing, you can access the online documentation in Xcode's `Help` menu.

NSObject

`NSObject` is the root of the entire Objective-C class hierarchy. Some commonly used methods on **`NSObject`** are described next.

```
- (id)init
```

Initializes the receiver after memory for it has been allocated. An **`init`** message is generally coupled with an **`alloc`** message in the same line of code:

```
TheClass *newObject = [[TheClass alloc] init];
```

```
- (NSString *)description
```

Returns an **NSString** that describes the receiver. The debugger's print object command ("po") invokes this method. A good **description** method will often make debugging easier. Also, if you use %@ in a format string, the object that should be substituted in is sent the message **description**. The value returned by the **description** method is put into the log string. For example, the line in your main function

```
NSLog(@"The number at index %d is %@", i, numberToPrint);
```

is equivalent to

```
NSLog(@"The number at index %d is %@", i,
                            [numberToPrint description]);
```

```
- (BOOL)isEqual:(id)anObject
```

Returns YES if the receiver and anObject are equal and NO otherwise. You might use it like this:

```
if ([myObject isEqual:anotherObject]) {
    NSLog(@"They are equal.");
}
```

But what does equal really mean? In **NSObject**, this method is defined to return YES if and only if the receiver and anObject are the same object—that is, if both are pointers to the same memory location.

Clearly, this is not always the "equal" that you would hope for, so this method is overridden by many classes to implement a more appropriate idea of equality. For example, **NSString** overrides the method to compare the characters in the receiver and anObject. If the two strings have the same characters in the same order, they are considered equal.

Thus, if x and y are **NSStrings**, there is a big difference between these two expressions:

```
x == y
```

and

```
[x isEqual:y]
```

The first expression compares the two pointers. The second expression compares the characters in the strings. Note, however, that if x and y are instances of a class that has not overridden **NSObject**'s **isEqual:** method, the two expressions are equivalent.

NSArray

An **`NSArray`** is a list of pointers to other objects. It is indexed by integers. Thus, if there are *n* objects in the array, the objects are indexed by the integers 0 through *n* – 1. You cannot put a `nil` in an **`NSArray`**. (This means that there are no "holes" in an **`NSArray`**, which may confuse some programmers who are used to Java's `Object[]`.) **`NSArray`** inherits from **`NSObject`**.

An **`NSArray`** is created with all the objects that will ever be in it. You can neither add nor remove objects from an instance of **`NSArray`**. We say that **`NSArray`** is *immutable*. (Its mutable subclass, **`NSMutableArray`**, will be discussed next.) Immutability is nice in some cases. Because it is immutable, a horde of objects can share one **`NSArray`** without worrying that one object in the horde might change it. **`NSString`** and **`NSNumber`** are also immutable. Instead of changing a string or number, you will simply create another one with the new value. (In the case of **`NSString`**, there is also the class **`NSMutableString`** that allows its instances to be altered.)

A single array can hold objects of many different classes. Arrays cannot, however, hold C primitive types, such as `int` or `float`.

Here are some commonly used methods implemented by **`NSArray`**:

```
- (unsigned)count
```

Returns the number of objects currently in the array.

```
- (id)objectAtIndex:(unsigned)i
```

Returns the object located at index `i`. If `i` is beyond the end of the array, you will get an error at runtime.

```
- (id)lastObject
```

Returns the object in the array with the highest index value. If the array is empty, `nil` is returned.

```
- (BOOL)containsObject:(id)anObject
```

Returns `YES` if `anObject` is present in the array. This method determines whether an object is present in the array by sending an **`isEqual:`** message to each of the array's objects and passing `anObject` as the parameter.

```
- (unsigned)indexOfObject:(id)anObject
```

Searches the receiver for `anObject` and returns the lowest index whose corresponding array value is equal to `anObject`. Objects are considered equal if **`isEqual:`** returns `YES`. If none of the objects in the array are equal to `anObject`, **`indexOfObject:`** returns `NSNotFound`.

NSMutableArray

`NSMutableArray` inherits from **`NSArray`** but extends it with the ability to add and remove objects. To create a mutable array from an immutable one, use **`NSArray`**'s **`mutableCopy`** method.

Here are some commonly used methods implemented by **`NSMutableArray`**:

```
- (void)addObject:(id)anObject
```

Inserts `anObject` at the end of the receiver. You are not allowed to add `nil` to the array.

```
- (void)addObjectsFromArray:(NSArray *)otherArray
```

Adds the objects contained in `otherArray` to the end of the receiver's array of objects.

```
- (void)insertObject:(id)anObject atIndex:(unsigned)index
```

Inserts `anObject` into the receiver at `index`, which cannot be greater than the number of elements in the array. If `index` is already occupied, the objects at `index` and beyond are shifted up one slot to make room. You will get an error if `anObject` is `nil` or if `index` is greater than the number of elements in the array.

```
- (void)removeAllObjects
```

Empties the receiver of all its elements.

```
- (void)removeObject:(id)anObject
```

Removes all occurrences of `anObject` in the array. Matches are determined on the basis of `anObject`'s response to the **`isEqual:`** message.

```
- (void)removeObjectAtIndex:(unsigned)index
```

Removes the object at `index` and moves all elements beyond `index` down one slot to fill the gap. You will get an error if `index` is beyond the end of the array.

As mentioned earlier, you cannot add `nil` to an array. Sometimes, you will want to put an object into an array to represent nothingness. The **`NSNull`** class exists for exactly this purpose. There is exactly one instance of **`NSNull`**, so if you want to put a placeholder for nothing into an array, use **`NSNull`** like this:

```
[myArray addObject:[NSNull null]];
```

NSString

An **`NSString`** is a buffer of Unicode characters. In Cocoa, all manipulations involving character strings are done with **`NSString`**. As a convenience, the Objective-C language also supports the `@"…"` construct to create a string object constant from a 7-bit ASCII encoding:

```
NSString *temp = @"this is a constant string";
```

`NSString` inherits from **`NSObject`**. Here are some commonly used methods implemented by **`NSString`**:

```
- (id)initWithFormat:(NSString *)format, ...
```

Works like **`sprintf`**. Here, `format` is a string containing tokens, such as `%d`. The additional arguments are substituted for the tokens:

```
int x = 5;
char *y = "abc";
id z = @"123";
NSString *aString = [[NSString alloc] initWithFormat:
            @"The int %d, the C String %s, and the NSString %@",
            x, y, z];
```

```
- (NSUInteger)length
```

Returns the number of characters in the receiver.

```
- (NSString *)stringByAppendingString:(NSString *)aString
```

Returns a string object made by appending `aString` to the receiver. The following code snippet, for example, would produce the string "Error: unable to read file."

```
NSString *errorTag = @"Error: ";
NSString *errorString = @"unable to read file.";
NSString *errorMessage;
errorMessage = [errorTag stringByAppendingString:errorString];
```

```
- (NSComparisonResult)compare:(NSString *)otherString
```

Compares the receiver and `otherString` and returns `NSOrderedAscending` if the receiver is alphabetically prior to `otherString`, `NSOrderedDescending` if `otherString` is comes before the receiver, or `NSOrderedSame` if the receiver and `otherString` are equal.

```
- (NSComparisonResult)caseInsensitiveCompare:(NSString *)
otherString
```

Like **`compare:`**, except the comparison ignores letter case.

"Inherits from" versus "Uses" or "Knows About"

Beginning Cocoa programmers are often eager to create subclasses of **`NSString`** and **`NSMutableArray`**. Don't. Stylish Objective-C programmers almost never do. Instead, they use **`NSString`** and **`NSMutableArray`** as parts of larger objects, a technique known as composition. For example, a **`BankAccount`** class *could* be a subclass of **`NSMutableArray`**. After all, isn't a bank account simply a collection of transactions? The beginner would follow this path. In contrast, the old hand would create a class **`BankAccount`** that inherited from **`NSObject`** and has an instance variable called `transactions` that would point to an **`NSMutableArray`**.

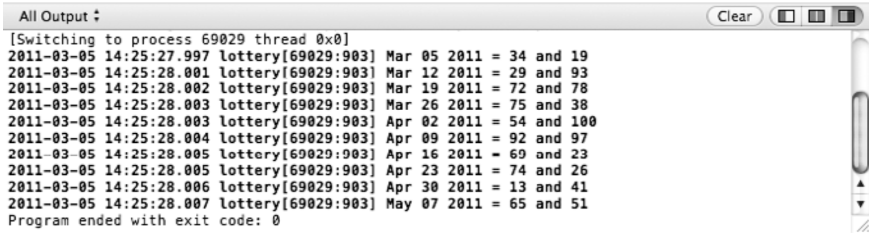
It is important to keep track of the difference between "uses" and "is a subclass of." The beginner would say, "**`BankAccount`** inherits from **`NSMutableArray`**." The old hand would say, "**`BankAccount`** uses **`NSMutableArray`**." In the common idioms of Objective-C, "uses" is much more common than "is a subclass of."

You will find it much easier to use a class than to subclass one. Subclassing involves more code and requires a deeper understanding of the superclass. By using composition instead of inheritance, Cocoa developers can take advantage of very powerful classes without really understanding how they work.

In a strongly typed language, such as C++, inheritance is crucial. In an untyped language, such as Objective-C, inheritance is just a hack that saves the developer some typing. There are only two inheritance diagrams in this entire book. All the other diagrams are object diagrams that indicate which objects know about which other objects. This is much more important information to a Cocoa programmer.

Creating Your Own Classes

Where I live, the state government has decided that the uneducated have entirely too much money: You can play the lottery every week. Let's imagine that a lottery entry has two numbers between 1 and 100, inclusive. You will write a program that will make up lottery entries for the next ten weeks. Each **`LotteryEntry`** object will have a date and two random integers (Figure 3.5).



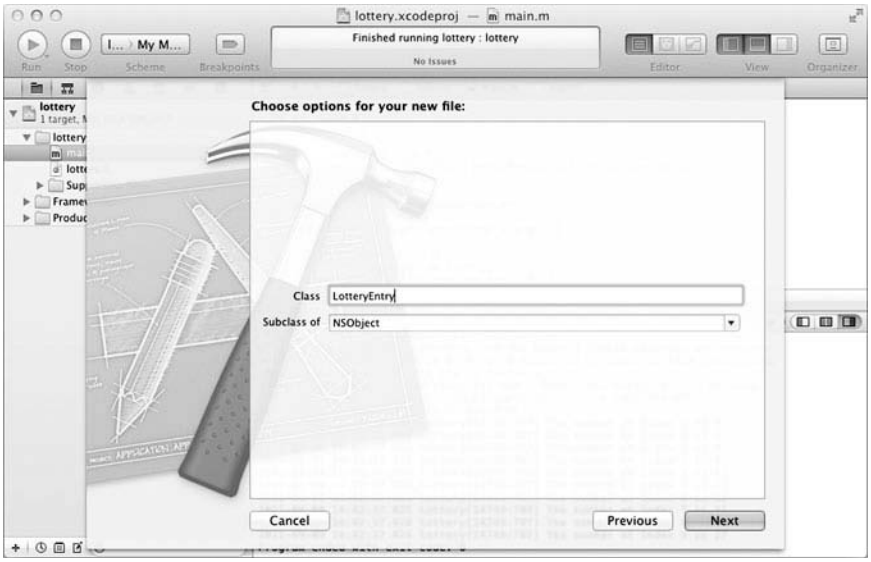
```
[Switching to process 69029 thread 0x0]
2011-03-05 14:25:27.997 lottery[69029:903] Mar 05 2011 = 34 and 19
2011-03-05 14:25:28.001 lottery[69029:903] Mar 12 2011 = 29 and 93
2011-03-05 14:25:28.002 lottery[69029:903] Mar 19 2011 = 72 and 78
2011-03-05 14:25:28.003 lottery[69029:903] Mar 26 2011 = 75 and 38
2011-03-05 14:25:28.003 lottery[69029:903] Apr 02 2011 = 54 and 100
2011-03-05 14:25:28.004 lottery[69029:903] Apr 09 2011 = 92 and 97
2011-03-05 14:25:28.005 lottery[69029:903] Apr 16 2011 = 69 and 23
2011-03-05 14:25:28.005 lottery[69029:903] Apr 23 2011 = 74 and 26
2011-03-05 14:25:28.006 lottery[69029:903] Apr 30 2011 = 13 and 41
2011-03-05 14:25:28.007 lottery[69029:903] May 07 2011 = 65 and 51
Program ended with exit code: 0
```

Figure 3.5 Completed Program

Besides learning how to create classes, you will build a tool that will certainly make you fabulously wealthy.

Creating the LotteryEntry Class

In Xcode, create a new file. Select Objective-C class as the type. Name the class **`LotteryEntry`**, and set it to be a subclass of **`NSObject`** (Figure 3.6).



Choose options for your new file:

Class LotteryEntry

Subclass of NSObject

Figure 3.6 New LotteryEntry Class

Note that you are also causing `LotteryEntry.h` to be created. Drag both files into the lottery group if they are not already there.

LotteryEntry.h

Edit the `LotteryEntry.h` file to look like this:

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

@interface LotteryEntry : NSObject {
    NSDate *entryDate;
    int firstNumber;
    int secondNumber;
}
```

```
- (void)prepareRandomNumbers;
- (void)setEntryDate:(NSDate *)date;
- (NSDate *)entryDate;
- (int)firstNumber;
- (int)secondNumber;
@end
```

You have created a header file for a new class called **`LotteryEntry`** that inherits from **`NSObject`**. It has three instance variables:

- `entryDate` is an **`NSDate`**.
- `firstNumber` and `secondNumber` are both `int`s.

You have declared five methods in the new class:

- **`prepareRandomNumbers`** will set `firstNumber` and `secondNumber` to random values between 1 and 100. It takes no arguments and returns nothing.
- **`entryDate`** and **`setEntryDate:`** will allow other objects to read and set the variable `entryDate`. The method **`entryDate`** will return the value stored in the `entryDate` variable. The method **`setEntryDate:`** will allow the value of the `entryDate` variable to be set. Methods that allow variables to be read and set are called *accessor methods*.
- You have also declared accessor methods for reading `firstNumber` and `secondNumber`. (You have not declared accessors for setting these variables; you are going to set them directly in **`prepareRandomNumbers`**.)

LotteryEntry.m

Edit `LotteryEntry.m` to look like this:

```
#import "LotteryEntry.h"

@implementation LotteryEntry

- (void)prepareRandomNumbers
{
    firstNumber = ((int)random() % 100) + 1;
    secondNumber = ((int)random() % 100) + 1;
}

- (void)setEntryDate:(NSDate *)date
{
    entryDate = date;
}
```

```
- (NSDate *)entryDate
{
    return entryDate;
}

- (int)firstNumber
{
    return firstNumber;
}

- (int)secondNumber
{
    return secondNumber;
}
@end
```

Here is the play-by-play for each method:

> **prepareRandomNumbers** uses the standard **random** function to generate a pseudorandom number. You use the mod operator (%) and add 1 to get the number in the range 1–100.
>
> **setEntryDate:** sets the pointer `entryDate` to a new value.
>
> **entryDate**, **firstNumber**, and **secondNumber** return the values of variables.

Changing main.m

Now let's look at `main.m`. Many of the lines have stayed the same, but several have changed. The most important change is that we are using **LotteryEntry** objects instead of **NSNumber** objects.

Here is the heavily commented code. (You don't have to type in the comments.)

```
#import <Foundation/Foundation.h>
#import "LotteryEntry.h"

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

    @autoreleasepool {

        // Create the date object
        NSDate *now = [[NSDate alloc] init];
        NSCalendar *cal = [NSCalendar currentCalendar];
        NSDateComponents *weekComponents =
            [[NSDateComponents alloc] init];
        // Seed the random number generator
        srandom((unsigned)time(NULL));
        NSMutableArray *array;
        array = [[NSMutableArray alloc] init];

        int i;
        for (i = 0; i < 10; i++) {

            [weekComponents setWeek:i];

            // Create a date/time object that is 'i' weeks from now
            NSDate *iWeeksFromNow;
            iWeeksFromNow = [cal dateByAddingComponents:weekComponents
                                                 toDate:now
                                                options:0];

            // Create a new instance of LotteryEntry
            LotteryEntry *newEntry = [[LotteryEntry alloc] init];
            [newEntry prepareRandomNumbers];
            [newEntry setEntryDate:iWeeksFromNow];

            // Add the LotteryEntry object to the array
            [array addObject:newEntry];

        }

        for (LotteryEntry *entryToPrint in array) {
            // Display its contents
            NSLog(@"%@", entryToPrint);
        }
    }
    return 0;
}
```

Note the second loop. Here you are using Objective-C's mechanism for enumerating over the members of a collection.

This program will create an array of `LotteryEntry` objects, as shown in Figure 3.7.

Implementing a description Method

Build and run your application. You should see something like Figure 3.8.

Hmm. Not quite what we hoped for. After all, the program is supposed to reveal the dates and the numbers you should play on those dates, and you can't see either. (You are seeing the default **`description`** method as defined in **`NSObject`**.) Next, you will make the **`LotteryEntry`** objects display themselves in a more meaningful manner.

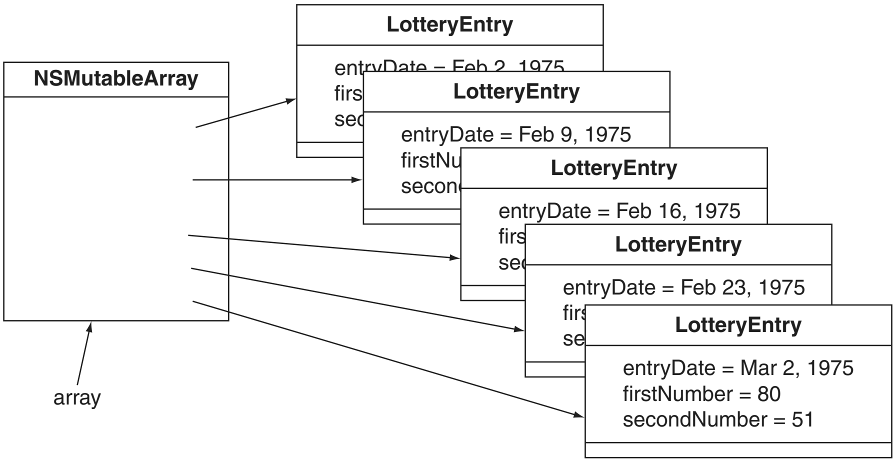
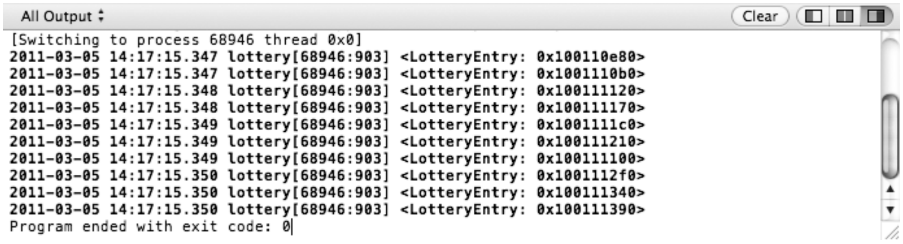


Figure 3.7 Object Diagram



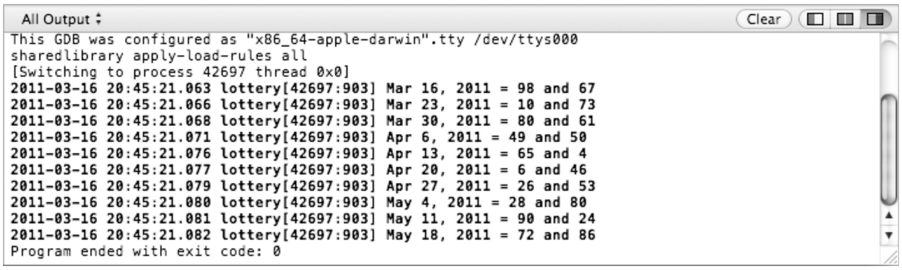
```
[Switching to process 68946 thread 0x0]
2011-03-05 14:17:15.347 lottery[68946:903] <LotteryEntry: 0x100110e80>
2011-03-05 14:17:15.347 lottery[68946:903] <LotteryEntry: 0x1001110b0>
2011-03-05 14:17:15.348 lottery[68946:903] <LotteryEntry: 0x100111120>
2011-03-05 14:17:15.348 lottery[68946:903] <LotteryEntry: 0x100111170>
2011-03-05 14:17:15.349 lottery[68946:903] <LotteryEntry: 0x1001111c0>
2011-03-05 14:17:15.349 lottery[68946:903] <LotteryEntry: 0x100111210>
2011-03-05 14:17:15.349 lottery[68946:903] <LotteryEntry: 0x100111100>
2011-03-05 14:17:15.350 lottery[68946:903] <LotteryEntry: 0x1001112f0>
2011-03-05 14:17:15.350 lottery[68946:903] <LotteryEntry: 0x100111340>
2011-03-05 14:17:15.350 lottery[68946:903] <LotteryEntry: 0x100111390>
Program ended with exit code: 0
```

Figure 3.8 Completed Execution

Add a **description** method to `LotteryEntry.m`:

```
- (NSString *)description
{
    NSDateFormatter *df = [[NSDateFormatter alloc] init];
    [df setTimeStyle:NSDateFormatterNoStyle];
    [df setDateStyle:NSDateFormatterMediumStyle];
    NSString *result;
    result = [[NSString alloc] initWithFormat:@"%@ = %d and %d",
              [df stringFromDate:entryDate],
              firstNumber, secondNumber];
    return result;
}
```

Build and run the application. Now you should see the dates and numbers:



```
This GDB was configured as "x86_64-apple-darwin".tty /dev/ttys000
sharedlibrary apply-load-rules all
[Switching to process 42697 thread 0x0]
2011-03-16 20:45:21.063 lottery[42697:903] Mar 16, 2011 = 98 and 67
2011-03-16 20:45:21.066 lottery[42697:903] Mar 23, 2011 = 10 and 73
2011-03-16 20:45:21.068 lottery[42697:903] Mar 30, 2011 = 80 and 61
2011-03-16 20:45:21.071 lottery[42697:903] Apr 6, 2011 = 49 and 50
2011-03-16 20:45:21.076 lottery[42697:903] Apr 13, 2011 = 65 and 4
2011-03-16 20:45:21.077 lottery[42697:903] Apr 20, 2011 = 6 and 46
2011-03-16 20:45:21.079 lottery[42697:903] Apr 27, 2011 = 26 and 53
2011-03-16 20:45:21.080 lottery[42697:903] May 4, 2011 = 28 and 80
2011-03-16 20:45:21.081 lottery[42697:903] May 11, 2011 = 90 and 24
2011-03-16 20:45:21.082 lottery[42697:903] May 18, 2011 = 72 and 86
Program ended with exit code: 0
```

Figure 3.9 Execution with Description

NSDate

Before moving on to any new ideas, let's examine **`NSDate`** in some depth. Instances of **`NSDate`** represent a single point in time and are basically immutable: You can't change the day or time once it is created. Because **`NSDate`** is immutable, many objects often share a single date object. There is seldom any need to create a copy of an **`NSDate`** object.

Here are some of the commonly used methods implemented by **`NSDate`**:

```
+ (id)date
```

Creates and returns a date initialized to the current date and time.

This is a *class method*. In the interface file, implementation file, and documentation, class methods are recognizable because they start with + instead of –. A class method is triggered by sending a message to the class instead of an instance. This one, for example, could be used as follows:

```
NSDate *now;
now = [NSDate date];
```

```
- (id)dateByAddingTimeInterval:(NSTimeInterval)interval
```

Creates and returns a date initialized to the date represented by the receiver *plus* the given `interval`.

```
- (NSTimeInterval)timeIntervalSinceDate:(NSDate *)anotherDate
```

Returns the interval in seconds between the receiver and `anotherDate`. If the receiver is earlier than `anotherDate`, the return value is negative. **`NSTimeInterval`** is the same as `double`.

`+ (NSTimeInterval)timeIntervalSinceReferenceDate`

Returns the interval in seconds between the first instant of January 1, 2001 GMT and the receiver's time.

`- (NSComparisonResult)compare:(NSDate *)otherDate`

Returns `NSOrderedAscending` if the receiver is earlier than `otherDate`, `NSOrderedDescending` if `otherDate` is earlier, or `NSOrderedSame` if the receiver and `otherDate` are equal.

Writing Initializers

Notice the following lines in your **`main`** function:

```
newEntry = [[LotteryEntry alloc] init];
[newEntry prepareRandomNumbers];
```

You are creating a new instance and then immediately calling **`prepareRandomNumbers`** to initialize `firstNumber` and `secondNumber`. This is something that should be handled by the initializer, so you are going to override the **`init`** method in your **`LotteryEntry`** class.

In the `LotteryEntry.m` file, change the method **`prepareRandomNumbers`** into an **`init`** method:

```
- (id)init
{
    self = [super init];
    if (self)
    {
        firstNumber = ((int)random() % 100) + 1;
        secondNumber = ((int)random() % 100) + 1;
    }
    return self;
}
```

The **`init`** method calls the superclass's initializer at the beginning, initializes its own variables, and then returns `self`, a pointer to the object itself (the object that is running this method). (If you are a Java or C++ programmer, `self` is the same as the `this` pointer.)

Now delete the following line in `main.m`:

```
[newEntry prepareRandomNumbers];
```

In `LotteryEntry.h`, delete the following declaration:

```
- (void)prepareRandomNumbers;
```

Build and run your program to reassure yourself that it still works.

Take another look at our **`init`** method. Why do we bother to assign the return value of the superclass's initializer to `self` and then test the value of `self`? The answer is that the initializers of some Cocoa classes will return `nil` if initialization was impossible. In order to handle these cases gracefully, we must both test the return value of `[super init]` and return the appropriate value for `self` from our initiailizer.

This pattern is debated among some Objective-C programmers. Some say that it is unnecessary, since most classes' initializers don't fail, and most classes' initializers don't return a different value for `self`. We believe it best to be in the habit of assigning to `self` and testing that value. The effort required is minimal compared to the debugging headaches that await you if you make an incorrect assumption about the superclass's behavior.

Initializers with Arguments

Look at the same place in `main.m`. It should now look like this:

```
LotteryEntry *newEntry = [[LotteryEntry alloc] init];
[newEntry setEntryDate:iWeeksFromNow];
```

It might be nicer if you could supply the date as an argument to the initializer. Change those lines to look like this:

```
LotteryEntry *newEntry = [[LotteryEntry alloc]
                                     initWithEntryDate:iWeeksFromNow];
```

You may see a compiler error; ignore it, as we are about to fix the problem.

Next, declare the method in `LotteryEntry.h`:

```
- (id)initWithEntryDate:(NSDate *)theDate;
```

Now, change (and rename) the **`init`** method in `LotteryEntry.m`:

```
- (id)initWithEntryDate:(NSDate *)theDate
{
    self = [super init];
    if (self)
    {
        entryDate = theDate;
        firstNumber = ((int)random() % 100) + 1;
        secondNumber = ((int)random() % 100) + 1;
    }
    return self;
}
```

Build and run your program. It should work correctly.

However, your class **LotteryEntry** has a problem. You are going to e-mail the class to your friend Rex. Rex plans to use the class **LotteryEntry** in his program but might not realize that you have written **initWithEntryDate:**. If he made this mistake, he might write the following lines of code:

```
NSDate *today = [NSDate date];
LotteryEntry *bigWin = [[LotteryEntry alloc] init];
[bigWin setEntryDate:today];
```

This code will not create an error. Instead, it will simply go up the inheritance tree until it finds **NSObject**'s **init** method. The problem is that `firstNumber` and `secondNumber` will not get initialized properly—both will be zero.

To protect Rex from his own ignorance, you will override **init** to call your initializer with a default date:

```
- (id)init
{
    return [self initWithEntryDate:[NSDate date]];
}
```

Add this method to your `LotteryEntry.m` file.

Note that **initWithEntryDate:** still does all the work. Because a class can have multiple initializers, we call the one that does the work the *designated initializer*. If a class has several initializers, the designated initializer typically takes the most arguments. You should clearly document which of your initializers is the designated initializer. Note that the designated initializer for **NSObject** is **init**.

Conventions for Creating Initializers (rules that Cocoa programmers try to follow regarding initializers):

- You do not have to create any initializer in your class if the superclass's initializers are sufficient.
- If you decide to create an initializer, you must override the superclass's designated initializer.

- If you create multiple initializers, only one does the work—the designated initializer. All other initializers call the designated initializer.
- The designated initializer of your class will call its superclass's designated initializer.

The day will come when you will create a class that must, must, must have some argument supplied. Override the superclass's designated initializer to throw an exception:

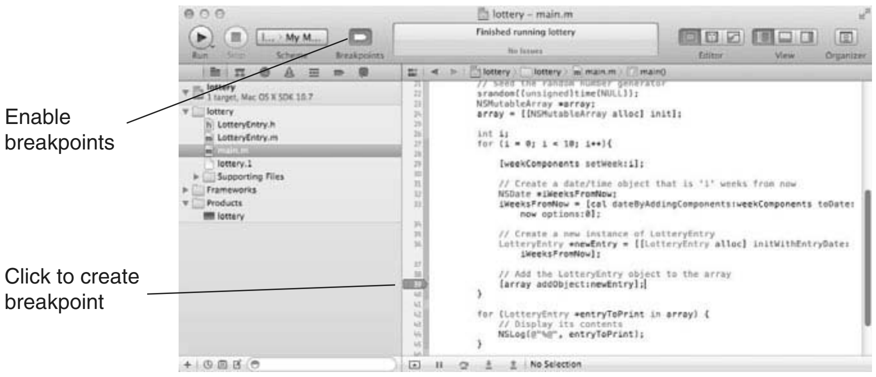
```
- (id)init
{
    @throw [NSException exceptionWithName:@"BNRBadInitCall"
                 reason:@"Initialize Lawsuit with initWithDefendant:"
               userInfo:nil];
    return nil;
}
```

The Debugger

The Free Software Foundation developed the compiler (gcc) and the debugger (gdb) that come with Apple's developer tools. Apple has made significant improvements to both over the years. This section discusses the processes of setting breakpoints, invoking the debugger, and browsing the values of variables.

While browsing code, you may have noticed a gray margin to the left of your code. If you click in that margin, a breakpoint will be added at the corresponding line. Add a breakpoint in `main.m` at the following line (Figure 3.10):

```
[array addObject:newEntry];
```



```
    // Seed the random number generator
    srandom((unsigned)time(NULL));
    NSMutableArray *array;
    array = [[NSMutableArray alloc] init];

    int i;
    for (i = 0; i < 10; i++){

        [weekComponents setWeek:i];

        // Create a date/time object that is 'i' weeks from now
        NSDate *iWeeksFromNow;
        iWeeksFromNow = [cal dateByAddingComponents:weekComponents toDate:
            now options:0];

        // Create a new instance of LotteryEntry
        LotteryEntry *newEntry = [[LotteryEntry alloc] initWithEntryDate:
            iWeeksFromNow];

        // Add the LotteryEntry object to the array
        [array addObject:newEntry];
    }

    for (LotteryEntry *entryToPrint in array) {
        // Display its contents
        NSLog(@"%@", entryToPrint);
    }
```

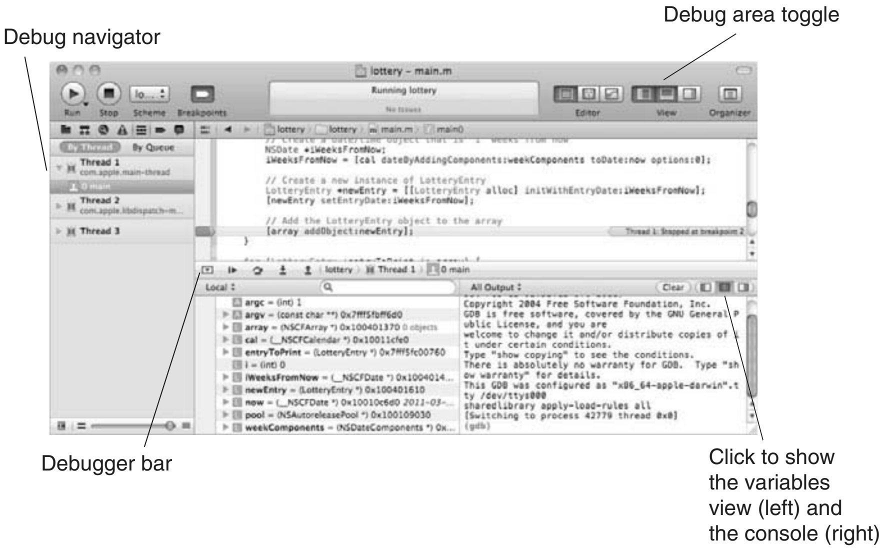
Figure 3.10 Creating a Breakpoint

When you run the program, Xcode will start the program in the debugger if you have any breakpoints. To test this, run it now. The debugger will take a few seconds to get started, and then it will run your program until it hits the breakpoint.

When your application is running, the debugger bar will be shown below the editor area. The debugger bar contains a button to toggle visibility of the full debugger area, including the variables view and console, as well as buttons to control the execution of your program and information about the current thread and function.

Xcode's default behavior is to show the full debugger area when a breakpoint is hit. If you do not see the debugger area at the bottom of the window, use the debugger area view toggle in the debugger bar (or toolbar), or the View->Show Debugger Area menu item.

You should also see the Debug navigator on the left, which shows the threads in our application and frames on the stack for each thread. Because the breakpoint is in **`main()`**, the stack is not very deep. In the variables view on the left in the debugger area, you can see the variables and their values (Figure 3.11).



```
NSDate *iWeeksFromNow;
iWeeksFromNow = [cal dateByAddingComponents:weekComponents toDate:now options:0];

// Create a new instance of LotteryEntry
LotteryEntry *newEntry = [[LotteryEntry alloc] initWithEntryDate:iWeeksFromNow];
[newEntry setEntryDate:iWeeksFromNow];

// Add the LotteryEntry object to the array
[array addObject:newEntry];
}
```

```
argc = (int) 1
argv = (const char **) 0x7fff5fbff6d0
array = (NSCFArray *) 0x100401370 0 objects
cal = (__NSCFCalendar *) 0x10011cfe0
entryToPrint = (LotteryEntry *) 0x7fff5fc00760
i = (int) 0
iWeeksFromNow = (__NSCFDate *) 0x1004014...
newEntry = (LotteryEntry *) 0x100401610
now = (__NSCFDate *) 0x10010c6d0 2011-03-...
pool = (NSAutoreleasePool *) 0x100109030
weekComponents = (NSDateComponents *) 0x...
```

```
Copyright 2004 Free Software Foundation, Inc.
GDB is free software, covered by the GNU General P
ublic License, and you are
welcome to change it and/or distribute copies of i
t under certain conditions.
Type "show copying" to see the conditions.
There is absolutely no warranty for GDB.  Type "sh
ow warranty" for details.
This GDB was configured as "x86_64-apple-darwin".t
ty /dev/ttys000
sharedlibrary apply-load-rules all
[Switching to process 42779 thread 0x0]
(gdb)
```

Figure 3.11 Stopped at a Breakpoint

Note that the variable `i` is currently 0.

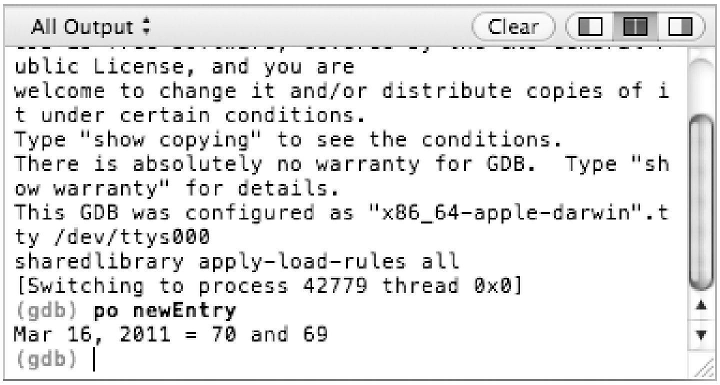
Return your attention to the debugger bar. Four of the buttons above the variables view are for pausing (or continuing) and stepping over, into, and out of functions. Click the `Continue` button to execute another iteration of the loop. Click the `Step-Over` button to walk through the code line by line.

The gdb debugger, being a Unix thing, was designed to be run from a terminal. When execution is paused, the gdb terminal will appear in the Console panel.

In the debug console, you have full access to all of gdb's capabilities. One very handy feature is "print-object" (po). If a variable is a pointer to an object, when you po it, the object is sent the message **`description`**, and the result is printed in the console. Try printing the `newEntry` variable.

```
po newEntry
```

You should see the result of your **`description`** method (Figure 3.12).



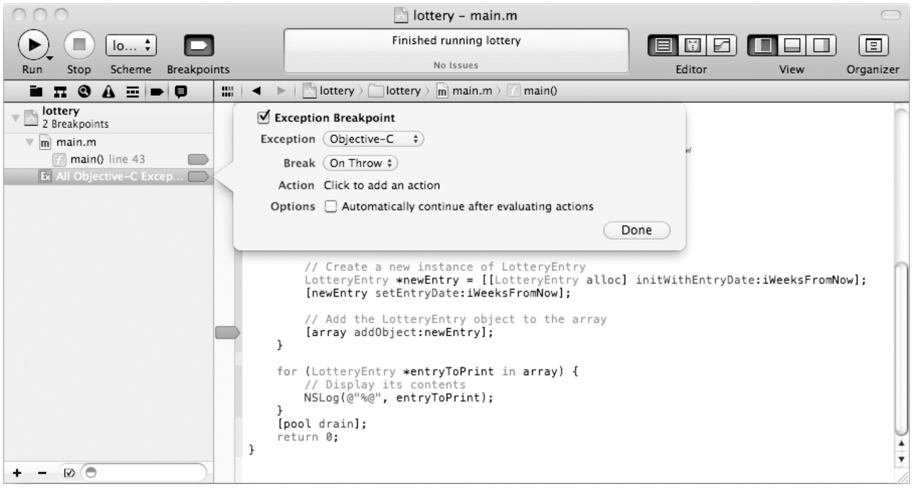
```
ublic License, and you are
welcome to change it and/or distribute copies of i
t under certain conditions.
Type "show copying" to see the conditions.
There is absolutely no warranty for GDB.  Type "sh
ow warranty" for details.
This GDB was configured as "x86_64-apple-darwin".t
ty /dev/ttys000
sharedlibrary apply-load-rules all
[Switching to process 42779 thread 0x0]
(gdb) po newEntry
Mar 16, 2011 = 70 and 69
(gdb) |
```

Figure 3.12 Using the gdb Console

Exceptions are raised when something goes very wrong. To make the debugger stop whenever an exception is thrown, you will want to add an exception breakpoint. Click the Add button at the bottom of the breakpoint navigator and select Add Exception Breakpoint.... Set the exception type to Objective-C and click Done (Figure 3.13). Disable the existing breakpoint in `main()` by clicking on the blue breakpoint icon in the breakpoint navigator. The breakpoint will be dimmed when it is disabled.

You can test this exception breakpoint by asking for an index that is not in an array. Immediately after the array is created, ask it what its first object is:

```
array = [[NSMutableArray alloc] init];
NSLog(@"first item = %@", [array objectAtIndex:0]);
```



Exception Breakpoint
Exception: Objective-C
Break: On Throw
Action: Click to add an action
Options: ☐ Automatically continue after evaluating actions

```
        // Create a new instance of LotteryEntry
        LotteryEntry *newEntry = [[LotteryEntry alloc] initWithEntryDate:iWeeksFromNow];
        [newEntry setEntryDate:iWeeksFromNow];

        // Add the LotteryEntry object to the array
        [array addObject:newEntry];
    }

    for (LotteryEntry *entryToPrint in array) {
        // Display its contents
        NSLog(@"%@", entryToPrint);
    }
    [pool drain];
    return 0;
}
```

Figure 3.13 Adding an Exception Breakpoint

Rebuild and restart the program. It should stop when the exception is raised.

One of the challenging things about debugging Cocoa programs is that they will often limp along in a broken state for quite a while. Using the macro **`NSAssert()`**, you can get the program to throw an exception as soon as the train leaves the track. For example, in **`setEntryDate:`**, you might want an exception thrown if the argument is `nil`. Add a call to **`NSAssert()`**:

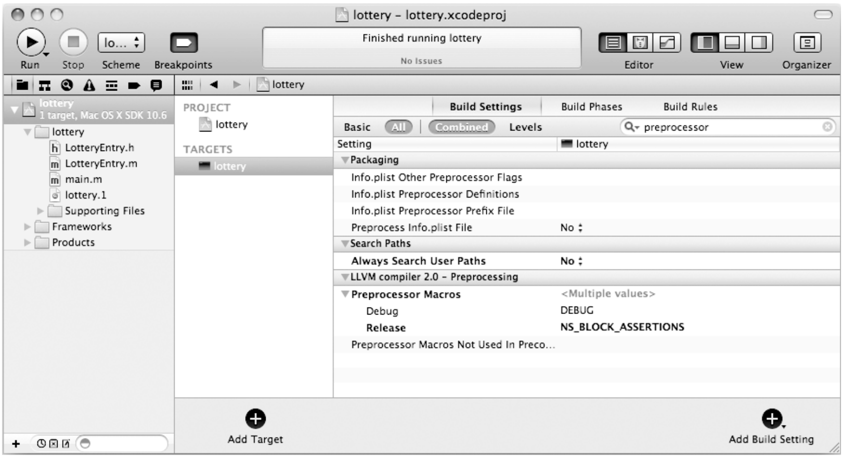
```
- (id)initWithEntryDate:(NSDate *)theDate
{
    self = [super init];
    if (self) {
        NSAssert(theDate != nil, @"Argument must be non-nil");
        entryDate = theDate;
        firstNumber = ((int)random() % 100) + 1;
        secondNumber = ((int)random() % 100) + 1;
    }
    return self;
}
```

Build it and run it. Your code, being correct, will not throw an exception. So change the assertion to something incorrect:

```
NSAssert(theDate == nil, @"Argument must be non-nil");
```

Now build and run your application. Note that a message, including the name of the class and method, is logged and an exception is thrown. Wise use of **`NSAssert()`** can help you hunt down bugs much more quickly.

You probably do not need your assert calls checked in your completed product. On most projects, there are two build configurations: Debug and Release. In the Debug version, you will want all your asserts checked. In the Release configuration, you will not. You will typically block assertion checking in the Release configuration (Figure 3.14).



```
Setting                                         lottery
▼Packaging
  Info.plist Other Preprocessor Flags
  Info.plist Preprocessor Definitions
  Info.plist Preprocessor Prefix File
  Preprocess Info.plist File                    No
▼Search Paths
  Always Search User Paths                      No
▼LLVM compiler 2.0 - Preprocessing
▼Preprocessor Macros                            <Multiple values>
    Debug                                       DEBUG
    Release                                     NS_BLOCK_ASSERTIONS
  Preprocessor Macros Not Used In Preco...
```

Figure 3.14 Disabling Assertion Checking

To do this, bring up the build settings by selecting the lottery project in the project navigator (topmost item). Then select the `lottery` target, change to the Build Settings tab, and find the Preprocessor Macros item. A quick way to find it is to use the search field at the top of the Build Settings panel. The Preprocessor Macros item will have one item beneath it for each build configuration: `Debug` and `Release`. Set the Release item value to `NS_BLOCK_ASSERTIONS`.

Now, if you build and run the Release configuration, you'll see that your assertion is not getting checked. (Before going on, fix your assertion: It should ensure that dates are *not* nil.)

You can change your current build configuration to Release by opening the scheme editor (in the Product menu, click Edit Scheme...). Select the Run action; on the `Info` panel, change Build Configuration to Release. Now when you build and run your application, it will be built using the Release configuration. Note that the default build configuration for the Archive action is Release. We will discuss build configurations in more detail in Chapter 37.

`NSAssert()` works only inside Objective-C methods. If you need to check an assertion in a C function, use **`NSCAssert()`**.

That's enough to get you started with the debugger. For more in-depth information, refer to the documentation from the Free Software Foundation (www.gnu.org/).

What Have You Done?

You have written a simple program in Objective-C, including a **`main()`** function that created several objects. Some of these objects were instances of **`LotteryEntry`**, a class that you created. The program logged some information to the console.

At this point, you have a fairly complete understanding of Objective-C. Objective-C is not a complex language. The rest of the book is concerned with the frameworks that make up Cocoa. From now on, you will be creating event-driven applications, not command-line tools.

Meet the Static Analyzer

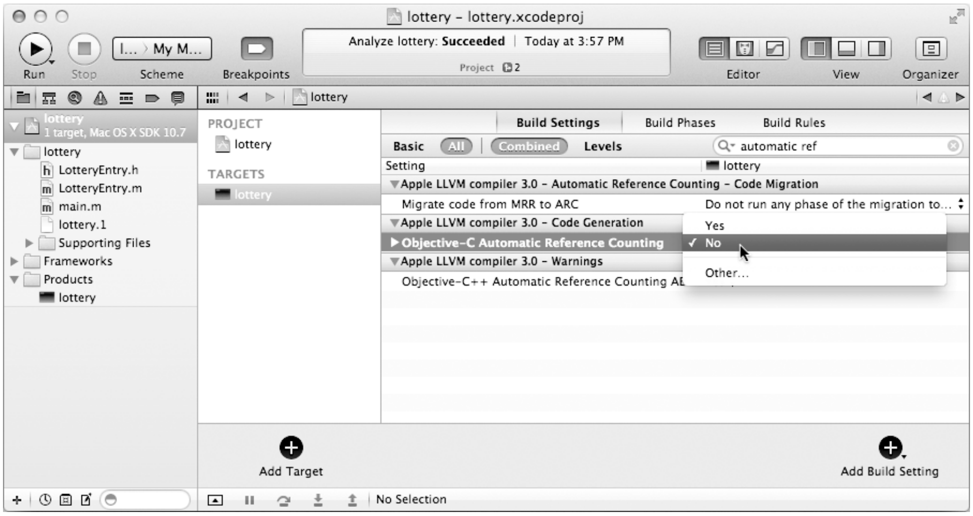
One of the handiest tools in Xcode is the static analyzer. The static analyzer uses Apple's LLVM compiler technology to analyze your code and find bugs. Traditionally, developers have relied on compiler warnings for hints on potential trouble areas in their code. The static analyzer goes much deeper, looking past syntax and tracing how values are used within your code.

Because of the default compiler settings and our careful typing, you should find, if you run the analyzer now, that our application has no issues as it stands. Let's modify our project settings so that we can better see the static analyzer at work.

As we did before, open the project's build settings by selecting the project in the project navigator on the left. Then select the lottery target. In the Build Settings tab, find the setting for Objective-C Automatic Reference Counting. Change its value to No (Figure 3.15).

Now analyze the lottery application. In the Product menu, click Analyze. In the issues navigator, you will see several issues found by the static analyzer; select one and drill down in the tree to examine the analyzer's thought process (Figure 3.16).

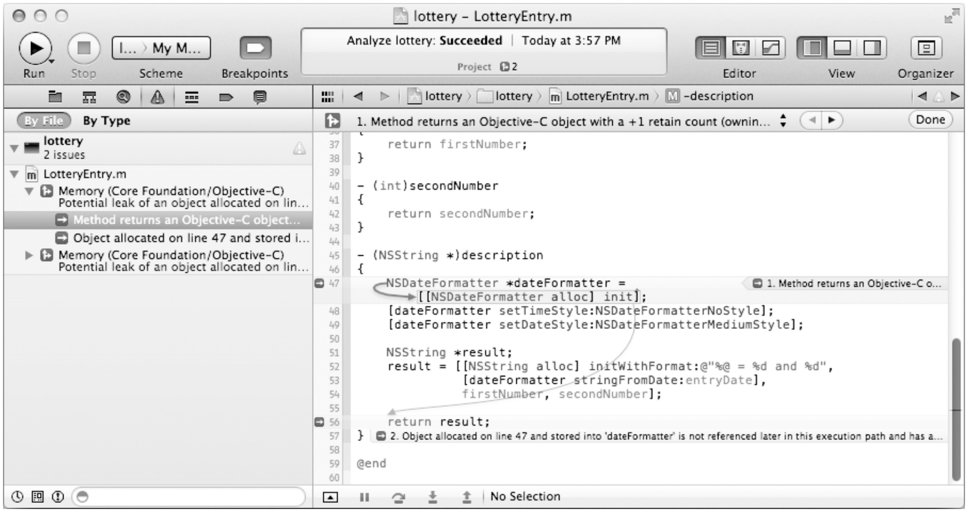
In this case, the static analyzer has found a number of memory-related problems in our program because we disabled a feature called automatic reference counting, which we will discuss in the next chapter. This is one of the more



Analyze lottery: **Succeeded** | Today at 3:57 PM

Setting	lottery
▼Apple LLVM compiler 3.0 – Automatic Reference Counting – Code Migration	
Migrate code from MRR to ARC	Do not run any phase of the migration to…
▼Apple LLVM compiler 3.0 – Code Generation	
▶Objective-C Automatic Reference Counting	Yes [✓ No] Other…
▼Apple LLVM compiler 3.0 – Warnings	
Objective-C++ Automatic Reference Counting AE	

Figure 3.15 Disable Automatic Reference Counting



Analyze lottery: **Succeeded** | Today at 3:57 PM

lottery
2 issues
LotteryEntry.m
Memory (Core Foundation/Objective-C)
Potential leak of an object allocated on lin…
Method returns an Objective-C object…
Object allocated on line 47 and stored i…
Memory (Core Foundation/Objective-C)
Potential leak of an object allocated on lin…

1. Method returns an Objective-C object with a +1 retain count (ownin…

```
    return firstNumber;
}

- (int)secondNumber
{
    return secondNumber;
}

- (NSString *)description
{
    NSDateFormatter *dateFormatter =
        [[NSDateFormatter alloc] init];
    [dateFormatter setTimeStyle:NSDateFormatterNoStyle];
    [dateFormatter setDateStyle:NSDateFormatterMediumStyle];

    NSString *result;
    result = [[NSString alloc] initWithFormat:@"%@ = %d and %d",
              [dateFormatter stringFromDate:entryDate],
              firstNumber, secondNumber];

    return result;
}

@end
```

1. Method returns an Objective-C o…

2. Object allocated on line 47 and stored into 'dateFormatter' is not referenced later in this execution path and has a…

Figure 3.16 The Static Analyzer at Work

useful aspects of the static analyzer: It knows the rules for retain-count memory management in Objective-C, and it can also identify other dangerous patterns in your code.

Leave automatic reference counting disabled for now.

For the More Curious: How Does Messaging Work?

As mentioned earlier, an object is like a C struct. **`NSObject`** declares an instance variable called `isa`. Because **`NSObject`** is the root of the entire class inheritance tree, every object has an `isa` pointer to the class structure that created the object (Figure 3.17). The class structure includes the names and types of the instance variables for the class. It also has the implementation of the class's methods. The class structure has a pointer to the class structure for its superclass.

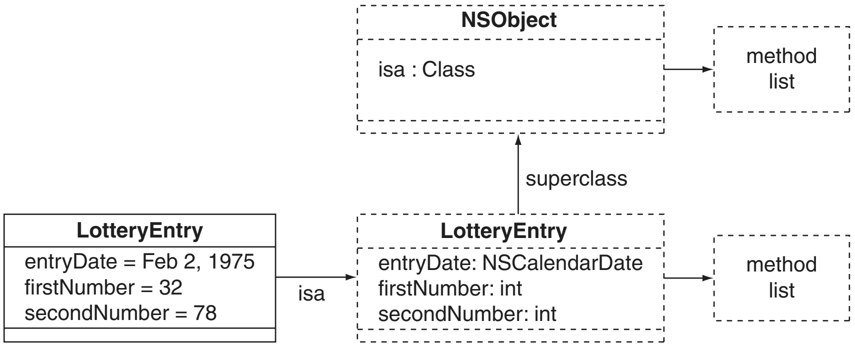
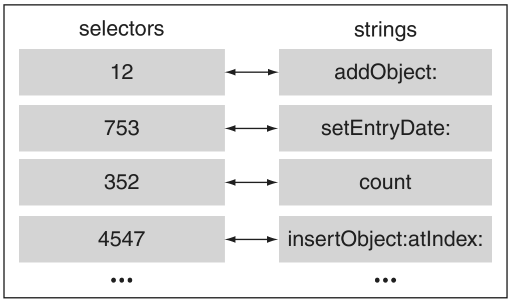


Figure 3.17 Each Object Has a Pointer to Its Class

The methods are indexed by the selector. The selector is of type `SEL`. Although `SEL` is defined to be `char *`, it is most useful to think of it as an `int`. Each method name is mapped to a unique `int`. For example, the method name **`addObject:`** might map to the number 12. When you look up methods, you will use the selector, not the string `@"addObject:"`.

As part of the Objective-C data structures, a table maps the names of methods to their selectors. Figure 3.18 shows an example.



selectors	strings
12	addObject:
753	setEntryDate:
352	count
4547	insertObject:atIndex:
...	...

Figure 3.18 The Selector Table

At compile time, the compiler looks up the selectors wherever it sees a message send. Thus,

```
[myObject addObject:yourObject];
```

becomes (assuming that the selector for **`addObject:`** is 12)

```
objc_msgSend(myObject, 12, yourObject);
```

Here, **`objc_msgSend()`** looks at `myObject`'s `isa` pointer to get to its class structure and looks for the method associated with 12. If it does not find the method, it follows the pointer to the superclass. If the superclass does not have a method for 12, it continues searching up the tree. If it reaches the top of the tree without finding a method, the function throws an exception.

Clearly, this is a very dynamic way of handling messages. These class structures can be changed at runtime. In particular, using the **`NSBundle`** class makes it relatively easy to add classes and methods to your program while it is running. This very powerful technique has been used to create applications that can be extended by other developers.

Challenge

Use **`NSDateFormatter`**'s **`setDateFormat:`** to customize the format string on the date objects in your **`LotteryEntry`** class.

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