

CHAPTER 10



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CODING FOR COLLECTIONS

LEARNING OBJECTIVES

- *ENABLE USER-DEFINED data types TO PERFORM CORRECTLY IN COLLECTIONS*
- *DEFINE THE TERM “NATURAL ORDERING”*
- *STATE THE DIFFERENCE BETWEEN NATURAL ORDERING AND CUSTOM ORDERING*
- *CREATE CLASSES AND STRUCTURES THAT CAN BE USED IN EQUALITY COMPARISONS*
- *OVERRIDE SYSTEM.OBJECT.EQUALS() AND SYSTEM.OBJECT.GETHASHCODE() METHODS*
- *IMPLEMENT THE ICOMPARABLE AND ICOMPARABLE<T> INTERFACES TO SPECIFY NATURAL ORDERING*
- *IMPLEMENT THE ICOMPARER AND ICOMPARER<T> INTERFACES TO CREATE A CUSTOM COMPARER*
- *IMPLEMENT THE IEQUATABLE INTERFACE TO ALLOW OBJECTS TO BE USED AS KEYS*
- *DEFINE THE TERM “IMMUTABLE” OBJECT*

INTRODUCTION

When creating user-defined data types you must stop for a moment to consider how they will be used in your program. If you intend to use them in collections then you must enable them to be used in equality and comparison operations. For example, if you intend to sort user-defined objects using the `Array.Sort()` method, then you must provide the ability for one object to be compared with another for the sort operation to work correctly. If you intend to use user-defined data types as keys in hashtables, dictionaries, or other keyed collections, then you'll need to know how to get your objects to behave correctly as keys. These topics are the focus of this chapter.

I'll start by showing you how to override the `Object.Equals()` and `Object.GetHashCode()` methods. I'll then explain why and how to overload the `==` and `!=` operators.

Next I'll talk about comparison operations and show you how to specify *natural ordering* by implementing the `IComparable` and `IComparable<T>` interfaces. Following this I'll show you how to create individual comparer objects that are used to specify *custom ordering* by implementing the `IComparer` and `IComparer<T>` interfaces.

I wrap up the chapter by showing you how to create objects that can be used as keys in hashtables, dictionaries, and other keyed collections. This includes a discussion of *object immutability*.

Upon completing this chapter you'll have a thorough understanding of how to create user-defined types that behave well when used in collections. Now, let's get going!

CODING FOR EQUALITY OPERATIONS

Objects of a particular type, when used in non-keyed collections like arrays and lists, must be able to be used in equality comparison operations. This section discusses the differences between *reference equality*, *value equality*, and *bitwise equality*, and shows you how to override the `Object.Equals()` and `Object.GetHashCode()` methods. Following this I'll show you how to overload the `==` and `!=` operators.

REFERENCE EQUALITY VS. VALUE EQUALITY

Normally, when you compare two reference objects for equality like this...

```
o1 == o2
```

...you are comparing their addresses. In other words, if `o1` and `o2` refer to the same location in memory then they must be equal because they refer to the same object. However, it's not always desirable to use an object's address as a basis for equality. Take strings for example. Two strings of equal value may be different objects as the following code snippet suggests:

```
String s1 = "Hello";
String s2 = "Hello";
```

The expression `(s1 == s2)` will yield true just as `s1.Equals(s2)` will yield true. This is because the `Equals()` method has been overridden and the `==` operator has been overloaded to perform a *value* or string content comparison, which is what you'd expect when comparing two strings.

For structures, the default behavior of the `Object.Equals()` method and the `==` operator is *bitwise equality*. For the most part, bitwise equality means the same thing as value equality, especially in the case of simple value types. (i.e., structures like `Int32`) If, however, the binary representation of the value type is complex, like the `Decimal` structure, then the `Object.Equals()` method is overridden and the `==` operator is overloaded to yield the expected value comparison behavior. For example, given two integer variables:

```
int i = 1;
int j = 2;
```

The expression `(i == j)` compares the value of `i`, which is 1, against the value of `j`, which is 2. In either case you can substitute the `==` operator with the `Equals()` method like so:

```
i.Equals(j);
```

OVERRIDING `OBJECT.EQUALS()` AND `OBJECT.GETHASHCODE()`

If the default behavior of the `Object.Equals()` method is insufficient for your user-defined data types, you'll need to override it and provide a custom implementation. Both the `Object.Equals()` and `Object.GetHashCode()` methods must be overridden together to ensure correct behavior. The following sections present the rules that should be followed when overriding these methods.

RULES FOR OVERRIDING THE `OBJECT.EQUALS()` METHOD

When overriding the `Object.Equals()` method, you must ensure that it subscribes to the expected behavior as specified in the .NET Framework documentation. Table 10.1 lists the required behavior of an overridden `Object.Equals()` method. (**Note:** The overloaded `==` operator must work the same way!)

Should be...	Rule	Comment
Reflexive	<code>x.Equals(x)</code> returns true	Exception: floating-point types
Symmetric	<code>x.Equals(y)</code> returns the same as <code>y.Equals(x)</code>	
Transitive	<code>(x.Equals(y) && y.Equals(z))</code> returns true if and only if <code>x.Equals(z)</code> returns true	
Consistent	Successive calls to <code>x.Equals(y)</code> return the same value as long as the objects referenced by <code>x</code> and <code>y</code> remain unchanged.	
	<code>x.Equals(null)</code> returns false	Or a null reference
	<code>x.Equals(y)</code> returns true if both <code>x</code> and <code>y</code> are NaN	NaN means Not a Number
	Calls to <code>Object.Equals()</code> must not throw exceptions.	No exceptions!
	Override the <code>Object.GetHashCode()</code> method.	If you override the <code>Object.Equals()</code> method.

Table 10-1: Rules for Overriding `Object.Equals()` method

RULES FOR OVERRIDING THE `OBJECT.GETHASHCODE()` METHOD

When you override the `Object.Equals()` method you should also override the `Object.GetHashCode()` method to ensure proper object behavior. This section presents two approaches to implementing a suitable `GetHashCode()` method. Now, don't be alarmed when I reference two very good Java books. The techniques used to create a suitable hashcode algorithm apply equally to C# as well as Java.

The `GetHashCode()` method returns an integer which is referred to as the object's *hash value*. The default implementation of `GetHashCode()` found in the `Object` class will, in most cases, return a unique hash value for each distinct object even if they are logically equivalent. In most cases this default behavior is acceptable, however, if you intend to use a class of objects as keys to hashtables or other hash-based data structures, then you must override the `GetHashCode()` method and obey the general contract as specified in the .NET Framework API documentation. The general contract for the `GetHashCode()` is given in Table 10-2.

Check	Criterion
	The <code>GetHashCode()</code> method must consistently return the same integer when invoked on the same object more than once during an execution of a C# or .NET application, provided no information used in <code>Equals()</code> comparisons on the object is modified. This integer need not remain constant from one execution of an application to another execution of the same application.

Table 10-2: The `GetHashCode()` General Contract

Check	Criterion
	The GetHashCode() method must produce the same results when called on two objects if they are equal according to the Equals() method.
	The GetHashCode() method is not required to return distinct integer results for logically unequal objects, however, failure to do so may result in degraded hash table performance.

Table 10-2: The GetHashCode() General Contract

As you can see from Table 10-2 there is a close relationship between the `Object.Equals()` and `Object.GetHashCode()` methods. It is recommended that any fields used in the `Equals()` method comparison be used to calculate an object's hash code. Remember, the primary goal when implementing a `GetHashCode()` method is to have it return the same value consistently for logically equal objects. It would also be nice if the `GetHashCode()` method returned distinct hash code values for logically unequal objects, but according to the general contract this is not a strict requirement.

Before actually implementing a `GetHashCode()` method, I want to provide you with two hash code generation algorithms. These algorithms come from two excellent Java references. (Yes, I meant to say Java.) I have changed the text to reflect the .NET method names `Object.Equals()` and `Object.GetHashCode()` respectively, and have converted Java operations into compatible C# .NET operations.

Bloch's Hash Code Generation Algorithm

Joshua Bloch, in his book *Effective Java™ Programming Language Guide*, provides the following algorithm for calculating a hash code:

1. Start by storing a constant, nonzero value in an `int` variable called `result`. (Josh used the value 17)
2. For each significant field *f* in your object (each field involved in the `Equals()` comparison) do the following:
 - a. Compute an `int` hash code *c* for the field:
 - i. If the field is boolean (`bool`) compute: `(f?0:1)`
 - ii. If the field is a byte, char, short, or int, compute: `(int)f`
 - iii. If the field is a long compute: `(unsigned)(f^(f >> 32))`
 - iv. If the field is a float compute: `Convert.ToInt32(f)`
 - v. If the field is a double compute: `Convert.ToInt64(f)`, and then hash the resulting long according to step 2.a.iii.
 - vi. If the field is an object reference and this class's `Equals()` method compares the field by recursively invoking `Equals()`, recursively invoke `GetHashCode()` on the field. If a more complex comparison is required, compute a "canonical representation" for this field and invoke `GetHashCode()` on the canonical representation. If the value of the field is null, return 0.
 - vii. If the field is an array, treat it as if each element were a separate field. That is, compute a hash code for each significant element by applying these rules recursively, and combine these values in step 2.b
 - b. Combine the hash code *c* computed in step a into `result` as follows:


```
result = 37*result + c;
```
3. Return `result`.
4. If equal object instances do not have equal hash codes fix the problem!

Ashmore's Hash Code Generation Algorithm

Derek Ashmore, in his book *The J2EE Architect's Handbook: How To Be A Successful Technical Architect For J2EE Applications*, recommends the following simplified hash code algorithm:

1. Concatenate the required fields (those involved in the `Equals()` comparison) into a string.
2. Call the `GetHashCode()` method on that string.
3. Return the resulting hash code value.

AN EXAMPLE: THE PERSON CLASS

I'll use a class named `Person` to demonstrate how to override the `Object.Equals()` and `Object.GetHashCode()` methods. Example 10.1 lists the code for the `Person` class.

10.1 Person.cs (Overridden Equals() and GetHashCode() Methods)

```

1      using System;
2
3      public class Person {
4
5          //enumeration
6          public enum Sex {MALE, FEMALE};
7
8          // private instance fields
9          private String  _firstName;
10         private String  _middleName;
11         private String  _lastName;
12         private Sex     _gender;
13         private DateTime _birthday;
14         private Guid    _dna;
15
16         public Person(){}
17
18         public Person(String firstName, String middleName, String lastName,
19                        Sex gender, DateTime birthday, Guid dna){
20             FirstName = firstName;
21             MiddleName = middleName;
22             LastName = lastName;
23             Gender = gender;
24             Birthday = birthday;
25             DNA = dna;
26         }
27
28         public Person(String firstName, String middleName, String lastName,
29                        Sex gender, DateTime birthday){
30             FirstName = firstName;
31             MiddleName = middleName;
32             LastName = lastName;
33             Gender = gender;
34             Birthday = birthday;
35             DNA = Guid.NewGuid();
36         }
37
38         public Person(Person p){
39             FirstName = p.FirstName;
40             MiddleName = p.MiddleName;
41             LastName = p.LastName;
42             Gender = p.Gender;
43             Birthday = p.Birthday;
44             DNA = p.DNA;
45         }
46
47         // public properties
48         public String FirstName {
49             get { return _firstName; }
50             set { _firstName = value; }
51         }
52
53         public String MiddleName {
54             get { return _middleName; }
55             set { _middleName = value; }
56         }
57
58         public String LastName {
59             get { return _lastName; }
60             set { _lastName = value; }
61         }
62
63         public Sex Gender {
64             get { return _gender; }
65             set { _gender = value; }
66         }
67
68         public DateTime Birthday {
69             get { return _birthday; }
70             set { _birthday = value; }
71         }
72
73         public Guid DNA {
74             get { return _dna; }

```

```

75     set { _dna = value; }
76 }
77
78 public int Age {
79     get {
80         int years = DateTime.Now.Year - _birthday.Year;
81         int adjustment = 0;
82         if(DateTime.Now.Month < _birthday.Month){
83             adjustment = 1;
84         } else if((DateTime.Now.Month == _birthday.Month) && (DateTime.Now.Day < _birthday.Day)){
85             adjustment = 1;
86         }
87         return years - adjustment;
88     }
89 }
90
91 public String FullName {
92     get { return FirstName + " " + MiddleName + " " + LastName; }
93 }
94
95 public String FullNameAndAge {
96     get { return FullName + " " + Age; }
97 }
98
99 public override String ToString(){
100     return (FullName + " " + Gender + " " + Age + " " + DNA);
101 }
102
103 public override bool Equals(object o){
104     if(o == null) return false;
105     if(typeof(Person) != o.GetType()) return false;
106     return this.ToString().Equals(o.ToString());
107 }
108
109 public override int GetHashCode(){
110     return this.ToString().GetHashCode();
111 }
112
113 } // end Person class

```

Referring to example 10.1 — the Person class defines the usual fields you'd expect for a data type of this nature. I've also added a field called `_dna` of type `Guid` (Globally Unique Identifier). (I know, I'm being cheeky here calling the field `_dna`. In real life, the name of this field might be `_id` which would map to the primary key column of a relational database table where state values of person objects are persisted.) I've added the `_dna` field with its corresponding `Guid` type to make it easier to make Person objects unique.

The overridden `Object.ToString()` method is defined on line 99. It returns a concatenation of the `FullName`, `Gender`, `Age`, and `DNA` properties. (The `Age` property is an example of a calculated read-only property.) The overridden `Object.Equals()` method starts on line 103. It relies on the `ToString()` method to compare different person objects for value equality. The `GetHashCode()` method simply calls the `GetHashCode()` method on the string generated by the Person object's `ToString()` method.

Example 10.2 gives the code for a short application that creates a few Person objects and tests the `Object.Equals()` method, validating its conformance to the rules laid out in table 10-1.

10.2 MainApp.cs (Demonstrating Overridden Equals() & GetHashCode() Methods)

```

1     using System;
2
3     public class MainApp {
4         public static void Main(){
5             Person p1 = new Person("Rick", "Warren", "Miller", Person.Sex.MALE,
6                 new DateTime(1961, 2, 3), Guid.NewGuid());
7             Console.WriteLine("p1.Equals(p1) : {0}", p1.Equals(p1));
8             Console.WriteLine("p1.Equals(string) : {0}", p1.Equals("Hello!"));
9             Person p2 = new Person("Steve", "Jacob", "Hester", Person.Sex.MALE,
10                new DateTime(1972, 1, 1), Guid.NewGuid());
11             Console.WriteLine("p1.Equals(p2) : {0}", p1.Equals(p2));
12             Console.WriteLine("p2.Equals(p1) : {0}", p2.Equals(p1));
13             Console.WriteLine("p1.GetHashCode() = {0}", p1.GetHashCode());
14             Console.WriteLine("p2.GetHashCode() = {0}", p2.GetHashCode());
15         }
16     }

```

Referring to example 10.2 — On line 5 a Person reference named `p1` is created and initialized. The `Object.Equals()` method is then called using the reference `p1` as an argument. This of course should return true. Next, `p1` is compared with a string object, which should return false. On line 9 a second Person reference named `p2` is declared and initialized and it's compared with `p1`. Both tests should return false. Following this, the `GetHashCode()`

method is called on each reference. The values returned by these last two method calls will yield different values when you run this program on your computer. Figure 10-1 shows the results of running this program.

```

C:\Collection Book Projects\Chapter_10\Equals_and_GetHashCode>MainApp
p1.Equals(p1) : True
p1.Equals(string) : False
p1.Equals(p2) : False
p2.Equals(p1) : False
p1.GetHashCode() = 2005557961
p2.GetHashCode() = 2141318955
C:\Collection Book Projects\Chapter_10\Equals_and_GetHashCode>_

```

Figure 10-1: Results of Running Example 10.2

OVERLOADING THE == AND != OPERATORS

Although not strictly required to be overloaded for the purposes of collections, the == and != operators can be overloaded with little effort because they can simply use the overridden Object.Equals() method in their implementation. (Low hanging fruit!) Example 10.3 gives the modified Person class with the overloaded == and != operators.

10.3 Person.cs (Overloaded == and != Operators)

```

1      using System;
2
3      public class Person {
4
5          //enumeration
6          public enum Sex {MALE, FEMALE};
7
8          // private instance fields
9          private String _firstName;
10         private String _middleName;
11         private String _lastName;
12         private Sex _gender;
13         private DateTime _birthday;
14         private Guid _dna;
15
16
17
18         public Person(){
19
20         public Person(String firstName, String middleName, String lastName,
21             Sex gender, DateTime birthday, Guid dna){
22             FirstName = firstName;
23             MiddleName = middleName;
24             LastName = lastName;
25             Gender = gender;
26             Birthday = birthday;
27             DNA = dna;
28         }
29
30         public Person(String firstName, String middleName, String lastName,
31             Sex gender, DateTime birthday){
32             FirstName = firstName;
33             MiddleName = middleName;
34             LastName = lastName;
35             Gender = gender;
36             Birthday = birthday;
37             DNA = Guid.NewGuid();
38         }
39
40         public Person(Person p){
41             FirstName = p.FirstName;
42             MiddleName = p.MiddleName;
43             LastName = p.LastName;
44             Gender = p.Gender;
45             Birthday = p.Birthday;
46             DNA = p.DNA;
47         }
48
49         // public properties
50         public String FirstName {

```

```

51     get { return _firstName; }
52     set { _firstName = value; }
53 }
54
55 public String MiddleName {
56     get { return _middleName; }
57     set { _middleName = value; }
58 }
59
60 public String LastName {
61     get { return _lastName; }
62     set { _lastName = value; }
63 }
64
65 public Sex Gender {
66     get { return _gender; }
67     set { _gender = value; }
68 }
69
70 public DateTime Birthday {
71     get { return _birthday; }
72     set { _birthday = value; }
73 }
74
75 public Guid DNA {
76     get { return _dna; }
77     set { _dna = value; }
78 }
79
80 public int Age {
81     get {
82         int years = DateTime.Now.Year - _birthday.Year;
83         int adjustment = 0;
84         if(DateTime.Now.Month < _birthday.Month){
85             adjustment = 1;
86         } else if((DateTime.Now.Month == _birthday.Month) && (DateTime.Now.Day < _birthday.Day)){
87             adjustment = 1;
88         }
89         return years - adjustment;
90     }
91 }
92
93 public String FullName {
94     get { return FirstName + " " + MiddleName + " " + LastName; }
95 }
96
97 public String FullNameAndAge {
98     get { return FullName + " " + Age; }
99 }
100
101 public override String ToString(){
102     return (FullName + " " + Gender + " " + Age + " " + DNA);
103 }
104
105 public override bool Equals(object o){
106     if(o == null) return false;
107     if(typeof(Person) != o.GetType()) return false;
108     return this.ToString().Equals(o.ToString());
109 }
110
111 public override int GetHashCode(){
112     return this.ToString().GetHashCode();
113 }
114
115 public static bool operator ==(Person lhs, Person rhs){
116     return lhs.Equals(rhs);
117 }
118
119 public static bool operator !=(Person lhs, Person rhs){
120     return !(lhs.Equals(rhs));
121 }
122
123 } // end Person class

```

Referring to example 10.3 — the == operator is overloaded on line 115. Note that it's a static method and that it defines two method parameters of type Person named lhs (left hand side) and rhs (right hand side). It simply calls the overridden Object.Equals() method to make the equality check. It can do this because the rules for overloading the == operator are the same as the rules for overriding the Object.Equals() method, so each must exhibit the same behavior.

The `!=` operator is defined on line 119. It too relies on the overridden `Object.Equals()` method in its implementation. Note that it simply negates the result of comparing the lhs with the rhs with the `Equals()` method.

Example 10.4 demonstrates the use of the overloaded `==` and `!=` operators.

10.4 MainApp.cs (Demonstrating Overloaded == and != Operators)

```

1      using System;
2
3      public class MainApp {
4          public static void Main(){
5              Person p1 = new Person("Rick", "Warren", "Miller", Person.Sex.MALE,
6                  new DateTime(1961, 2, 3), Guid.NewGuid());
7              Console.WriteLine("p1.Equals(p1) : {0}", p1.Equals(p1));
8              Console.WriteLine("p1.Equals(string) : {0}", p1.Equals("Hello!"));
9              Person p2 = new Person("Steve", "Jacob", "Hester", Person.Sex.MALE,
10                 new DateTime(1972, 1, 1), Guid.NewGuid());
11             Console.WriteLine("p1.Equals(p2) : {0}", p1.Equals(p2));
12             Console.WriteLine("p2.Equals(p1) : {0}", p2.Equals(p1));
13             Console.WriteLine("p1.GetHashCode() = {0}", p1.GetHashCode());
14             Console.WriteLine("p2.GetHashCode() = {0}", p2.GetHashCode());
15             Console.WriteLine("p1 == p1 : {0}", p1 == p1);
16             Console.WriteLine("p1 == p2 : {0}", p1 == p2);
17             Console.WriteLine("p1 != p1 : {0}", p1 != p1);
18             Console.WriteLine("p1 != p2 : {0}", p1 != p2);
19         }
20     }

```

Referring to example 10.4 — the tests of the `==` and `!=` operators have been added to the previous `MainApp` example. On line 15 the reference `p1` is compared with itself using the `==` operator and again on line 17 using the `!=` operator. These comparisons result in the compiler warnings shown in figure 10-2. You can safely ignore them here for the sake of testing. Figure 10-3 shows the results of running this program.

```

C:\Collection Book Projects\Chapter_10\Equals_and_NotEquals_Operators>csc *.cs
Microsoft (R) Visual C# 2008 Compiler version 3.5.30729.1
for Microsoft (R) .NET Framework version 3.5
Copyright (C) Microsoft Corporation. All rights reserved.

MainApp.cs(15,41): warning CS1718: Comparison made to same variable; did you mean to compare something else?
MainApp.cs(17,41): warning CS1718: Comparison made to same variable; did you mean to compare something else?

C:\Collection Book Projects\Chapter_10\Equals_and_NotEquals_Operators>_

```

Figure 10-2: Compiler Warning Generated when Compiling Examples 10.3 and 10.4

```

C:\Collection Book Projects\Chapter_10\Equals_and_NotEquals_Operators>MainApp
p1.Equals(p1) : True
p1.Equals(string) : False
p1.Equals(p2) : False
p2.Equals(p1) : False
p1.GetHashCode() = 2005557961
p2.GetHashCode() = 2141318955
p1 == p1 : True
p1 == p2 : False
p1 != p1 : False
p1 != p2 : True

C:\Collection Book Projects\Chapter_10\Equals_and_NotEquals_Operators>

```

Figure 10-3: Results of Running Example 10.4

Quick Review

The first step in getting your user-defined types to behave well in collections is to override the `Object.Equals()` and `Object.GetHashCode()` methods. Make sure you adhere to the `Object.Equals()` method behavior rules. You can optionally overload the `==` and `!=` methods as their behavior can be easily implemented in terms of the `Object.Equals()` method.

The overridden `Object.GetHashCode()` method can be easily implemented by calling the `GetHashCode()` method on the string returned by the object's overridden `ToString()` method.

CODING FOR COMPARISON OPERATIONS

If you intend to insert user-defined objects into a collection and sort them you'll need to define how, exactly, one object is to be compared with another in terms of being *less than*, *equal to*, or *greater than* another object. You do this by implementing either the *IComparable* or the *IComparable<T>* interfaces, or both if you plan to use user-defined objects in both non-generic and generic collections. In this section I explain the concept of natural ordering and show you how to implement each of these interfaces.

NATURAL ORDERING

When you implement the *IComparable* and *IComparable<T>* interfaces in a class or structure you are specifying what is referred to as a *natural ordering* for that particular type. It's called natural ordering because you have instructed the type how to behave when compared with other objects of the same (or different) type.

Take integers for example. If you examine the .NET documentation for the *Int32* structure you'll see that it implements both the *IComparable* and *IComparable<T>* (as *IComparable<int>*) interfaces. This allows integers to be compared with other integers when sorted with the *Sort()* method defined by the *Array* class and other collections that allow elements to be sorted.

IComparable AND *IComparable<T>* INTERFACES

The *IComparable* and *IComparable<T>* interfaces each declare one method named *CompareTo(object other)* that returns an integer, the value of which must reflect the results of the comparison as listed in the rules shown in table 10-3.

Return Value	Returned When...
Less than Zero (-1)	This object is less than the <i>other</i> parameter
Zero (0)	This object is equal to the <i>other</i> parameter
Greater than Zero (1)	This object is greater than the <i>other</i> parameter, or, the <i>other</i> parameter is null

Table 10-3: Rules For Implementing *IComparable.CompareTo()* Method

Referring to table 10-3 — as the rules state, if the object (represented by the *this* reference) is less than the *other* parameter, the *CompareTo()* method returns some value less than 0. (The value -1 is fine.) If both objects being compared are equal it returns 0, and if the *other* object is greater or *null* it returns a positive number. (1 is fine.) Example 10.5 shows how the *IComparable* and *IComparable<T>* interfaces can be implemented in the *Person* class.

10.5 *Person.cs* (Implementing *IComparable* and *IComparable<T>* Interfaces)

```

1      using System;
2
3      public class Person : IComparable, IComparable<Person> {
4
5          //enumeration
6          public enum Sex {MALE, FEMALE};
7
8          // private instance fields
9          private String _firstName;
10         private String _middleName;
11         private String _lastName;
12         private Sex _gender;
13         private DateTime _birthday;
14         private Guid _dna;
15
16
17
18         public Person(){
19

```

```

20     public Person(String firstName, String middleName, String lastName,
21                   Sex gender, DateTime birthday, Guid dna){
22         FirstName = firstName;
23         MiddleName = middleName;
24         LastName = lastName;
25         Gender = gender;
26         Birthday = birthday;
27         DNA = dna;
28     }
29
30     public Person(String firstName, String middleName, String lastName,
31                   Sex gender, DateTime birthday){
32         FirstName = firstName;
33         MiddleName = middleName;
34         LastName = lastName;
35         Gender = gender;
36         Birthday = birthday;
37         DNA = Guid.NewGuid();
38     }
39
40     public Person(Person p){
41         FirstName = p.FirstName;
42         MiddleName = p.MiddleName;
43         LastName = p.LastName;
44         Gender = p.Gender;
45         Birthday = p.Birthday;
46         DNA = p.DNA;
47     }
48
49     // public properties
50     public String FirstName {
51         get { return _firstName; }
52         set { _firstName = value; }
53     }
54
55     public String MiddleName {
56         get { return _middleName; }
57         set { _middleName = value; }
58     }
59
60     public String LastName {
61         get { return _lastName; }
62         set { _lastName = value; }
63     }
64
65     public Sex Gender {
66         get { return _gender; }
67         set { _gender = value; }
68     }
69
70     public DateTime Birthday {
71         get { return _birthday; }
72         set { _birthday = value; }
73     }
74
75     public Guid DNA {
76         get { return _dna; }
77         set { _dna = value; }
78     }
79
80     public int Age {
81         get {
82             int years = DateTime.Now.Year - _birthday.Year;
83             int adjustment = 0;
84             if(DateTime.Now.Month < _birthday.Month){
85                 adjustment = 1;
86             }else if((DateTime.Now.Month == _birthday.Month) && (DateTime.Now.Day < _birthday.Day)){
87                 adjustment = 1;
88             }
89             return years - adjustment;
90         }
91     }
92
93     public String FullName {
94         get { return FirstName + " " + MiddleName + " " + LastName; }
95     }
96
97     public String FullNameAndAge {
98         get { return FullName + " " + Age; }
99     }
100

```

```

101     protected String SortableName {
102         get { return LastName + FirstName + MiddleName; }
103     }
104
105     public override String ToString(){
106         return (FullName + " " + Gender + " " + Age + " " + DNA);
107     }
108
109     public override bool Equals(object o){
110         if(o == null) return false;
111         if(typeof(Person) != o.GetType()) return false;
112         return this.ToString().Equals(o.ToString());
113     }
114
115     public override int GetHashCode(){
116         return this.ToString().GetHashCode();
117     }
118
119     public static bool operator ==(Person lhs, Person rhs){
120         return lhs.Equals(rhs);
121     }
122
123     public static bool operator !=(Person lhs, Person rhs){
124         return !(lhs.Equals(rhs));
125     }
126
127     public int CompareTo(object obj){
128         if((obj == null) || (typeof(Person) != obj.GetType())) {
129             throw new ArgumentException("Object is not a Person!");
130         }
131         return this.SortableName.CompareTo(((Person)obj).SortableName);
132     }
133
134     public int CompareTo(Person p){
135         if(p == null){
136             throw new ArgumentException("Cannot compare null objects!");
137         }
138         return this.SortableName.CompareTo(p.SortableName);
139     }
140
141 } // end Person class

```

Referring to example 10.5 — on line 3 the `IComparable` and `IComparable<T>` interfaces are listed as being implemented by the `Person` class. Note how the `IComparable<T>` interface actually reads `IComparable<Person>`. The non-generic `CompareTo()` method begins on line 127. This version of the method corresponds with the `IComparable` interface. It takes an object argument and must test it to see if it's the proper type. If it's not, or it's `null`, it throws an `ArgumentException`.

The `CompareTo()` method on line 134 corresponds to the `IComparable<Person>` interface. Note that since the type of parameter has been specified, it's no longer necessary to explicitly test the incoming object for type conformance, as this is handled by the compiler.

Also important to note here is how I've defined natural ordering for `Person` objects. I've chosen to order `Person` objects by last names, first names, and middle names. To help in this effort I have added another property to the `Person` class named `SortableName` which concatenates the name fields together for proper sorting.

Example 10.6 demonstrates how an array of `Person` objects can now be sorted by name.

10.6 MainApp.cs (Sorting and Array of Person Objects with Natural Ordering)

```

1     using System;
2
3     public class MainApp {
4         public static void Main(){
5             Person p1 = new Person("Rick", "Warren", "Miller", Person.Sex.MALE,
6                 new DateTime(1961, 2, 3), Guid.NewGuid());
7             Person p2 = new Person("Steve", "Jacob", "Hester", Person.Sex.MALE,
8                 new DateTime(1972, 1, 1), Guid.NewGuid());
9             Person p3 = new Person("Coralie", "Sylvia", "Miller", Person.Sex.FEMALE,
10                new DateTime(1959, 8, 8), Guid.NewGuid());
11            Person p4 = new Person("Katherine", "Sport", "Reid", Person.Sex.FEMALE,
12                new DateTime(1970, 5, 6), Guid.NewGuid());
13            Person p5 = new Person("Kathleen", "KayakKat", "McMamee", Person.Sex.FEMALE,
14                new DateTime(1983, 2, 3), Guid.NewGuid());
15            Person p6 = new Person("Kyle", "Victor", "Miller", Person.Sex.MALE,
16                new DateTime(1986, 10, 15), Guid.NewGuid());
17
18            Person[] people_array = new Person[6];
19            people_array[0] = p1;
20            people_array[1] = p2;

```

```

21     people_array[2] = p3;
22     people_array[3] = p4;
23     people_array[4] = p5;
24     people_array[5] = p6;
25
26     Console.WriteLine("----- Before Sorting -----");
27
28     foreach(Person p in people_array){
29         Console.WriteLine(p.LastName + ", " + p.FirstName);
30     }
31
32     Array.Sort(people_array);
33
34     Console.WriteLine("----- After Sorting -----");
35
36     foreach(Person p in people_array){
37         Console.WriteLine(p.LastName + ", " + p.FirstName);
38     }
39 }
40

```

Referring to example 10.6 — the six `Person` objects created on lines 5 through 16 are used to initialize the six elements of the `people_array` on lines 19 through 24. The `foreach` statement on line 28 prints out the contents of the array to the console before sorting. The `foreach` statement on line 36 does the same after the array has been sorted. The `Array.Sort()` method called on line 32 expects the elements in the array passed to it as an argument to implement `IComparable`. If one or more elements in the array fail to implement `IComparable`, the `Sort()` method will throw an `InvalidOperationException`. Figure 10-4 shows the results of running this program.

```

c:\ Projects
C:\Collection Book Projects\Chapter_10\IComparable_and_IComparableT>mainapp
----- Before Sorting -----
Miller, Rick
Hester, Steve
Miller, Coralie
Reid, Katherine
McNamee, Kathleen
Miller, Kyle
----- After Sorting -----
Hester, Steve
McNamee, Kathleen
Miller, Coralie
Miller, Kyle
Miller, Rick
Reid, Katherine
C:\Collection Book Projects\Chapter_10\IComparable_and_IComparableT>_

```

Figure 10-4: Results of Running Example 10.6

CUSTOM ORDERING: CREATING SEPARATE COMPARER OBJECTS

As you learned in the preceding section, to specify a natural ordering for your user-defined types you must implement the `IComparable` and `IComparable<T>` interfaces. If you want to order objects in a different way, you can create custom comparers by implementing the `IComparer` and `IComparer<T>` interfaces.

IComparer AND IComparer<T> INTERFACES

The `IComparer` and `IComparer<T>` interfaces both declare one method named `Compare()`. In the case of `IComparer` the method signature is `int Compare(object x, object y)` and for `IComparer<T>` it's `int Compare(T x, T y)`. The rules for implementing the `Compare()` methods are the same ones used to implement the `CompareTo()` methods discussed in the previous section.

These methods are easy to implement. In most cases, custom ordering boils down to one particular field within the user-defined type. For example, if you want to provide a custom ordering of `Person` objects by age, you would simply be comparing two integers: one person object's age against another's. And since all the built-in .NET types already implement the `IComparable` and `IComparable<T>` interfaces, you can implement the `Compare()` method in terms of each object's `CompareTo()` method.

An Example: PERSONAGECOMPARER

Example 10.7 gives the code for a class named `PersonAgeComparer`. The `PersonAgeComparer` class implements both the `IComparer` and `IComparer<T>` interfaces.

10.7 *PersonAgeComparer.cs*

```

1  using System;
2  using System.Collections;
3  using System.Collections.Generic;
4
5  public class PersonAgeComparer : IComparer, IComparer<Person> {
6
7      public int Compare(object x, object y){
8          if((x == null) || (y == null) || (typeof(Person) != x.GetType())
9             || (typeof(Person) != y.GetType())){
10             throw new ArgumentException("Both objects must be of type Person!");
11         }
12
13         return ((Person)x).Age.CompareTo((Person)y.Age);
14     }
15
16     public int Compare(Person x, Person y){
17         if((x == null) || (y == null)){
18             throw new ArgumentException("Both objects must be of type Person!");
19         }
20
21         return x.Age.CompareTo(y.Age);
22     }
23 }
24

```

Referring to example 10.7 — the non-generic `Compare()` method starts on line 7. The `if` statement on line 8 checks to ensure incoming arguments are valid `Person` objects. If the arguments fail this test the method throws an `ArgumentException`. Line 13 contains the meat of the method: It casts each parameter to type `Person` and calls the `CompareTo()` method via the `x` parameter passing the `y` parameter as an argument. Done!

The generic version of the `Compare()` method on line 16 safely skips the type testing part of the `if` statement since the method parameters already specify the type. If the arguments are *null* it throws an `ArgumentException`, otherwise, the comparison of the `x` parameter with the `y` parameter proceeds without the casting as was necessary in the non-generic version of the `Compare()` method.

Example 10.8 demonstrates the use of the `PersonAgeComparer` class.

10.8 *MainApp.cs (Demonstrating Custom Ordering with PersonAgeComparer)*

```

1  using System;
2
3
4  public class MainApp {
5      public static void Main(){
6          Person p1 = new Person("Rick", "Warren", "Miller", Person.Sex.MALE,
7             new DateTime(1961, 2, 3), Guid.NewGuid());
8          Person p2 = new Person("Steve", "Jacob", "Hester", Person.Sex.MALE,
9             new DateTime(1972, 1, 1), Guid.NewGuid());
10         Person p3 = new Person("Coralie", "Sylvia", "Miller", Person.Sex.FEMALE,
11             new DateTime(1974, 8, 8), Guid.NewGuid());
12         Person p4 = new Person("Katherine", "Sport", "Reid", Person.Sex.FEMALE,
13             new DateTime(1970, 5, 6), Guid.NewGuid());
14         Person p5 = new Person("Kathleen", "KayakKat", "McMamee", Person.Sex.FEMALE,
15             new DateTime(1983, 2, 3), Guid.NewGuid());
16         Person p6 = new Person("Kyle", "Victor", "Miller", Person.Sex.MALE,
17             new DateTime(1986, 10, 15), Guid.NewGuid());
18
19         Person[] people_array = new Person[6];
20         people_array[0] = p1;
21         people_array[1] = p2;
22         people_array[2] = p3;
23         people_array[3] = p4;
24         people_array[4] = p5;
25         people_array[5] = p6;
26
27         Console.WriteLine("----- Before Sorting -----");
28
29         foreach(Person p in people_array){
30             Console.WriteLine(p.FullNameAndAge);
31         }
32
33         Array.Sort(people_array, new PersonAgeComparer());
34
35         Console.WriteLine("----- After Sorting -----");

```

```

36
37     foreach(Person p in people_array){
38         Console.WriteLine(p.FullNameAndAge);
39     }
40 }
41

```

Referring to example 10.8 — note on line 33 that a `PersonAgeComparer` object is passed as the second argument to the `Array.Sort()` method. If a custom comparer object is supplied to the `Array.Sort()` method, as is done here, it orders the elements in the array according to the custom comparer. The result in this case is that the elements are sorted by age vs. last, first, and middle names. Figure 10-5 shows the results of running this program.

Figure 10-5: Results of Running Example 10.8

Quick Review

Implement both the `IComparable` and `IComparable<T>` interfaces to specify a natural ordering for user-defined types. Implement the `IComparer` and `IComparer<T>` interfaces to create a custom comparer. Custom comparers are used to specify a custom ordering. You can create as many custom comparers as required.

It's a good idea to always implement both the generic and non-generic versions of these interfaces. Doing so ensures your user-defined types will be sortable in generic and non-generic collections.

Using Objects as Keys

In keyed collections, objects are inserted into the collection in key/value pairs. Object's used as keys must obey certain rules. This section explains those rules and demonstrates how to create a type suitable for the creation of key objects.

RULES FOR OBJECTS USED AS KEYS

Objects inserted into keyed collections are located within those collections via an operation performed upon their associated key. In chapter 9 you learned about the `Hashtable` and `Dictionary<T Key, T Value>` collections. In these collections, the value's location with the hash table is determined by applying a hash function to the key. Before an object can be used as a key it must adhere to a few rules as listed in table 10-4.

Rule	Comment
Key must be immutable	Objects used as keys must not change value while they are being used as keys. Object's whose state value cannot be changed after they are created are called immutable objects. Strings are immutable objects, which is why they can be safely used as keys.

Table 10-4: Rules For Creating Key Classes

Rule	Comment
Implement the <code>IEquatable<T></code> interface	The <code>IEquatable<T></code> interface is used by generic collections to test keys for equality. It defines one method named <code>Equals()</code> .
Override the <code>Object.Equals()</code> method	Key objects need to be compared with each other for equality. If you implement <code>IEquatable<T></code> you should also override the <code>Object.Equals()</code> method for consistency.
Override the <code>Object.GetHashCode()</code> method	Key objects, especially when used as keys in <code>Hashtable</code> and <code>Dictionary<T Key, T Value></code> collections, must override the <code>GetHashCode()</code> method. You must also override this method if you override <code>Object.Equals()</code> to ensure consistent equality behavior.
Implement <code>IComparable</code> and <code>IComparable<T></code> interfaces	If you're going to use the keys in sorted collections, the key objects must be sortable. If you don't implement these interfaces you can specify custom ordering by providing a custom comparer object.

Table 10-4: Rules For Creating Key Classes

Object Immutability

An immutable object is one whose state cannot be changed after it has been created. Strings are an example of immutable objects. One simple way to create an immutable type is to make the fields readonly and supply readonly properties. Object state values are set only through constructor methods. Care must also be taken not to return references to contained objects. Example 10.9 demonstrates this strategy.

10.9 MyImmutableType.cs

```

1      using System;
2
3      public class MyImmutableType {
4          private readonly string _stringValue;
5          private readonly int _intValue;
6
7          public MyImmutableType(string s, int i){
8              _stringValue = s;
9              _intValue = i;
10         }
11
12         public string StringValue {
13             get { return string.Copy(_stringValue); }
14         }
15
16         public int IntValue {
17             get { return _intValue; }
18         }
19
20         public override string ToString(){
21             return _stringValue + " " + _intValue;
22         }
23     }

```

Referring to example 10.9 — the `MyImmutableType` class contains two readonly fields: one of type `string` named `_stringValue` and one of type `int` named `_intValue`. The constructor supplies the only way to set these field values. The `StringValue` and `IntValue` properties are readonly properties. (i.e., they only supply `get` operations) Note how the `StringValue` property returns a copy of the `_stringValue` field. Example 10.10 shows the `MyImmutableType` class in action, although there's not much going on!

10.10 MainApp.cs (Demonstrating MyImmutableType)

```

1      using System;
2
3      public class MainApp {
4          public static void Main(){
5              MyImmutableType mit = new MyImmutableType("An immutable type's state cannot be changed.", 49);
6              Console.WriteLine(mit);
7          }
8      } // end Main

```

Figure 10-6 shows the results of running this program.

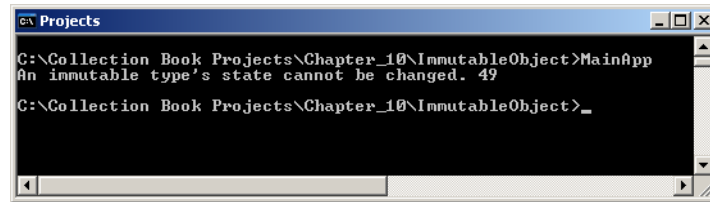


Figure 10-6: Results of Running Example 10.10

EXAMPLE: PERSONKEY CLASS

Example 10.11 gives an extended key class example in the form of the `PersonKey` class. The `PersonKey` class implements most of the rules listed in table 10-4. Note that if I wanted to use this key class in sorting operations I would need to implement the `IComparable` and `IComparable<T>` interfaces.

10.11 PersonKey.cs

```

1      using System;
2
3      public class PersonKey : IEquatable<String> {
4
5          private readonly string _keyString = String.Empty;
6
7          public PersonKey(string s){
8              _keyString = s;
9          }
10
11         public bool Equals(string other){
12             return _keyString.Equals(other);
13         }
14
15         public override string ToString(){
16             return String.Copy(_keyString);
17         }
18
19         public override bool Equals(object o){
20             if(o == null) return false;
21             if(typeof(string) != o.GetType()) return false;
22             return this.ToString().Equals(o.ToString());
23         }
24
25         public override int GetHashCode(){
26             return this.ToString().GetHashCode();
27         }
28     }
29

```

Referring to example 10.11 — the `PersonKey` class implements the `IEquatable<T>` interface (as `IEquatable<string>`). It also overrides the `Object.ToString()`, `Object.Equals()` and `Object.GetHashCode()` methods. It's also immutable, as the only way to set the `_keyString` field value is via the constructor.

Example 10.12 gives a modified version of the `Person` class that contains a new `Key` property of type `PersonKey`.

10.12 Person.cs (With Key Property)

```

1      using System;
2
3      public class Person : IComparable, IComparable<Person> {
4
5          //enumeration
6          public enum Sex {MALE, FEMALE};
7
8
9          // private instance fields
10         private String _firstName;
11         private String _middleName;
12         private String _lastName;
13         private Sex _gender;
14         private DateTime _birthday;
15         private Guid _dna;
16
17
18
19         public Person(){
20
21         public Person(String firstName, String middleName, String lastName,

```

```

22         Sex gender, DateTime birthday, Guid dna){
23     FirstName = firstName;
24     MiddleName = middleName;
25     LastName = lastName;
26     Gender = gender;
27     Birthday = birthday;
28     DNA = dna;
29 }
30
31 public Person(String firstName, String middleName, String lastName,
32             Sex gender, DateTime birthday){
33     FirstName = firstName;
34     MiddleName = middleName;
35     LastName = lastName;
36     Gender = gender;
37     Birthday = birthday;
38     DNA = Guid.NewGuid();
39 }
40
41 public Person(Person p){
42     FirstName = p.FirstName;
43     MiddleName = p.MiddleName;
44     LastName = p.LastName;
45     Gender = p.Gender;
46     Birthday = p.Birthday;
47     DNA = p.DNA;
48 }
49
50 // public properties
51 public String FirstName {
52     get { return _firstName; }
53     set { _firstName = value; }
54 }
55
56 public String MiddleName {
57     get { return _middleName; }
58     set { _middleName = value; }
59 }
60
61 public String LastName {
62     get { return _lastName; }
63     set { _lastName = value; }
64 }
65
66 public Sex Gender {
67     get { return _gender; }
68     set { _gender = value; }
69 }
70
71 public DateTime Birthday {
72     get { return _birthday; }
73     set { _birthday = value; }
74 }
75
76 public Guid DNA {
77     get { return _dna; }
78     set { _dna = value; }
79 }
80
81 public int Age {
82     get {
83         int years = DateTime.Now.Year - _birthday.Year;
84         int adjustment = 0;
85         if(DateTime.Now.Month < _birthday.Month){
86             adjustment = 1;
87         }else if((DateTime.Now.Month == _birthday.Month) && (DateTime.Now.Day < _birthday.Day)){
88             adjustment = 1;
89         }
90         return years - adjustment;
91     }
92 }
93
94 public String FullName {
95     get { return FirstName + " " + MiddleName + " " + LastName; }
96 }
97
98 public String FullNameAndAge {
99     get { return FullName + " " + Age; }
100 }
101
102 protected String SortableName {

```

```

103     get { return LastName + FirstName + MiddleName; }
104     }
105
106     public PersonKey Key {
107         get { return new PersonKey(this.ToString()); }
108     }
109
110     public override String ToString(){
111         return (FullName + " " + Gender + " " + Age + " " + DNA);
112     }
113
114     public override bool Equals(object o){
115         if(o == null) return false;
116         if(typeof(Person) != o.GetType()) return false;
117         return this.ToString().Equals(o.ToString());
118     }
119
120     public override int GetHashCode(){
121         return this.ToString().GetHashCode();
122     }
123
124     public static bool operator ==(Person lhs, Person rhs){
125         return lhs.Equals(rhs);
126     }
127
128     public static bool operator !=(Person lhs, Person rhs){
129         return !(lhs.Equals(rhs));
130     }
131
132     public int CompareTo(object obj){
133         if((obj == null) || (typeof(Person) != obj.GetType())) {
134             throw new ArgumentException("Object is not a Person!");
135         }
136         return this.SortableName.CompareTo((Person)obj.SortableName);
137     }
138
139     public int CompareTo(Person p){
140         if(p == null){
141             throw new ArgumentException("Cannot compare null objects!");
142         }
143         return this.SortableName.CompareTo(p.SortableName);
144     }
145 } // end Person class

```

Referring to example 10.12 — the Key property is defined on line 106. Note that a new instance of `PersonKey` is returned each time the Key property is accessed. Example 10.13 demonstrates how Person objects can be inserted into a `Dictionary<T Key, T Value>` collection with the help of the `PersonKey` key class.

10.13 MainApp.cs (Demonstrating the use of Person.Key Property with a Dictionary)

```

1     using System;
2     using System.Collections.Generic;
3
4
5     public class MainApp {
6         public static void Main(){
7             Person p1 = new Person("Rick", "Warren", "Miller", Person.Sex.MALE,
8                 new DateTime(1961, 2, 3), Guid.NewGuid());
9             Person p2 = new Person("Steve", "Jacob", "Hester", Person.Sex.MALE,
10                new DateTime(1972, 1, 1), Guid.NewGuid());
11            Person p3 = new Person("Coralie", "Sylvia", "Miller", Person.Sex.FEMALE,
12                new DateTime(1974, 8, 8), Guid.NewGuid());
13            Person p4 = new Person("Katherine", "Sport", "Reid", Person.Sex.FEMALE,
14                new DateTime(1970, 5, 6), Guid.NewGuid());
15            Person p5 = new Person("Kathleen", "KayakKat", "McMamee", Person.Sex.FEMALE,
16                new DateTime(1983, 2, 3), Guid.NewGuid());
17            Person p6 = new Person("Kyle", "Victor", "Miller", Person.Sex.MALE,
18                new DateTime(1986, 10, 15), Guid.NewGuid());
19
20            Dictionary<PersonKey, Person> directory = new Dictionary<PersonKey, Person>();
21            directory.Add(p1.Key, p1);
22            directory.Add(p2.Key, p2);
23            directory.Add(p3.Key, p3);
24            directory.Add(p4.Key, p4);
25            directory.Add(p5.Key, p5);
26            directory.Add(p6.Key, p6);
27
28            foreach(KeyValuePair<PersonKey, Person> kvp in directory){
29                Console.WriteLine("Key: {0} Value: {1}", kvp.Key, kvp.Value.FullName);
30            }
31        }
32    }

```

Referring to example 10.13 — each of the six person objects created on lines 7 through 18 are inserted into the dictionary using their Key properties. The `foreach` statement on line 28 iterates over the dictionary collection and writes the value of each key and its associated value to the console.

```

C:\Collection Book Projects\Chapter_10\PersonKey>MainApp
Key: Rick Warren Miller MALE 49 6cb3e4fc-e546-4062-985e-0a6232341adb Value: Rick Warren Miller
Key: Steve Jacob Hester MALE 38 7ca585df-64c6-4a8c-84ec-180fa50e9794 Value: Steve Jacob Hester
Key: Coralie Sylvia Miller FEMALE 35 19209628-d756-4e8e-ba60-2d8cfc82da51 Value: Coralie Sylvia Miller
Key: Katherine Sport Reid FEMALE 40 46f5d6a2-765e-4396-b4c8-b04ccha66196 Value: Katherine Sport Reid
Key: Kathleen KayakKat McMamee FEMALE 27 6d4137b6-181c-42a3-9824-6d3c4eebfcc6 Value: Kathleen KayakKat McMamee
Key: Kyle Victor Miller MALE 23 d688994e-f62b-43f7-b088-187d98da9f2f Value: Kyle Victor Miller
C:\Collection Book Projects\Chapter_10\PersonKey>

```

Figure 10-7: Results of Running Example 10.12

Quick Review

If an object is to be used as a key in a collection it must be immutable while it is being used as a key. Immutable object state value cannot be changed after the object is created. Key objects must also implement the `IEquatable<T>` interface and override the `Object.Equals()` and `Object.GetHashCode()` methods. Strings make ideal keys because they implement all the necessary interfaces and are immutable.

SUMMARY

The first step in getting your user-defined types to behave well in collections is to override the `Object.Equals()` and `Object.GetHashCode()` methods. Make sure you adhere to the `Object.Equals()` method behavior rules. You can optionally overload the `==` and `!=` methods as their behavior can be easily implemented in terms of the `Object.Equals()` method.

The overridden `Object.GetHashCode()` method be easily implemented by calling the `GetHashCode()` method on the string returned by the object's overridden `ToString()` method.

To specify a natural ordering for user-defined types, implement both the `IComparable` and `IComparable<T>` interfaces. To specify a custom ordering, create a custom comparer class by implementing the `IComparer` and `IComparer<T>` interfaces. It's a good idea to always implement both the generic and non-generic versions of these interfaces. Doing so ensures your user-defined types will be sortable in generic and non-generic collections.

If an object is to be used as a key in a collection it must be immutable while it is being used as a key. Immutable object state value cannot be changed after the object is created. Key objects must also implement the `IEquatable<T>` interface and override the `Object.Equals()` and `Object.GetHashCode()` methods. Strings make ideal keys because they implement all the necessary interfaces and are immutable.

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