

Generic Collections and LINQ

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Introduction to collection objects and LINQ

- .NET provides a set of pre-packaged data structures known as collections
 - They have been carefully designed to ensure robust and efficient performance
 - *Array*
 - Efficient random access but inefficient to resize it
 - *List*
 - Enables dynamic resizing but not random access

Introduction to collection objects and LINQ

- In addition, C# provides a mechanism for querying collections known as LINQ
 - *Language Integrated Query*
- LINQ enables access to collections (and databases!) using *query expressions* which are similar to SQL queries
 - This allows the retrieval of information from a wide variety of data sources

Introduction to collection objects and LINQ

- We will primarily look at *LINQ to Objects*
 - Enables the querying on collection objects
- .NET also provides LINQ providers for :
 - *LINQ to SQL*
 - For querying databases
 - *LINQ to XML*
 - For querying xml documents

Querying an array

- We can design a simple LINQ query which filters the contents of an array
 - Applying the query to the array causes all the values of the array which meet a certain criteria to be extracted
 - But the query doesn't say *how* the iteration through the array is performed
 - All the necessary code is generated by the compiler, the query just specifies the criteria

Querying an array

- A simple query object comprises *from*, *where* and *select* clauses
 - Also, we can make use of the keyword *var* which is an implicit type
 - Essentially a strongly typed local variable but the type is determined by the compiler
- In this case the type of the array is determined by the data source type

```
var filteredArray =  
    from .....    // range variable and data source  
    where .....    // boolean expression  
    select.....    // which value appears in the results
```

```
using System;
using System.Collections.Generic;
using System.Linq;

class LINQtoArray
{
    static void Main(string[] args)
    {
        int[] array = { 2, 6, 4, 12, 7, 8, 9, 13, 2 };

        var filteredArray =                // LINQ query
            from element in array
            where element < 7
            select element;

        PrintArray(filteredArray, "All values less than 7:");
    }

    public static void PrintArray(IEnumerable<int> arr, string message)
    {
        Console.Write("{0}", message);

        foreach (var element in arr)
            Console.Write(" {0}", element);

        Console.WriteLine();
    }
}
```


Querying an array

- *IEnumerable<T>* is an interface implemented by arrays and collections
- It is a *generic type*
 - We replace the *T* by a real type (such as an *int*)
 - More on this later

Querying an array

- We can add the *orderby* (descending) clause to our query to sort our filtered array into ascending (descending) order

```
var filteredArray =  
    from .....           // range variable and data source  
    where .....          // boolean expression  
    orderby ..... (descending) // sort  
    select.....          // which value appears in the results
```

```
using System;
using System.Collections.Generic;
using System.Linq;

class LINQtoArray
{
    static void Main(string[] args)
    {
        int[] array = { 2, 6, 4, 12, 7, 8, 9, 13, 2 };

        var filteredArray =                // LINQ query
            from element in array
            where element < 7
            select element;

        PrintArray(filteredArray, "All values less than 7:");

        var orderedFilteredArray =
            from element in filteredArray
            orderby element
            select element;

        PrintArray(orderedFilteredArray, "All values less than 7 and sorted:");
    }

    public static void PrintArray(IEnumerable<int> arr, string message)
    {.....}
}
```

Querying an array

- It's important to understand a feature of LINQ known as *deferred execution*
 - The result of a LINQ query expression **is not** a sequence or collection of objects but a **query object**
 - It represents the commands needed to execute the query
 - The query *does not execute until the program requests data from the query object*
 - Deferred execution is a powerful feature of LINQ as it allows applications to pass queries around as data
 - In our simple example, the query is not run until it is passed to the *PrintArray* method

Querying an array

- We can use LINQ to query an array of user defined objects or strings
- We must be careful when using *orderby*
 - The objects must be comparable
 - Comparable types in .NET implement the *IComparable<T>* interface
 - Built in primitive types automatically implement *IComparable<T>*
 - The '*T*' is a parameterised type
 - We will look at these in more detail later
- For example we can query an array of *StudentInfo* objects

```
class StudentInfo
{
    public StudentInfo(string ln, string fn, int id, string a)
    {
        lastName = ln; firstName = fn; idNumber = id; address = a;
    }

    public override string ToString()
    {
        return firstName+" "+lastName+" "+idNumber+" " +address;
    }

    public string FirstName
    {
        get { return firstName; }
    }

    public string LastName
    {
        get { return lastName; }
    }

    public string Address
    {
        get { return address; }
    }

    public int ID
    {
        get { return idNumber; }
    }

    private string firstName,lastName;
    private int idNumber;
    private string address;
}
```

Querying an array

- We can filter the array by ID number
 - Simply get the ID property of the range variable
- Also we can sort the names into last name order and then first name order using *orderby*
 - This uses the fact that the *string* type implements *IComparable<T>*

```

public class LINQtoObjectArray
{
    static void Main(string[] args)
    {
        StudentInfo[] students ={
            new StudentInfo("Smith", "John", 12345, "5 Bournbrook Rd"),
            new StudentInfo("Brown", "Alan", 23412, "Dawlish Rd"),
            new StudentInfo("Smith","Colin", 41253, "23 Bristol Rd"),
            new StudentInfo("Hughes", "Richard", 52314, "18 Prichatts Rd"),
            new StudentInfo("Murphy", "Paul", 16352, "37 College Rd") };

        // Filter a range of ID numbers
        var idRange=
            from s in students
            where s.ID>19999 && s.ID<=49999
            select s;

        PrintArray(idRange,"Students with ID in Range 2000 to 4999");

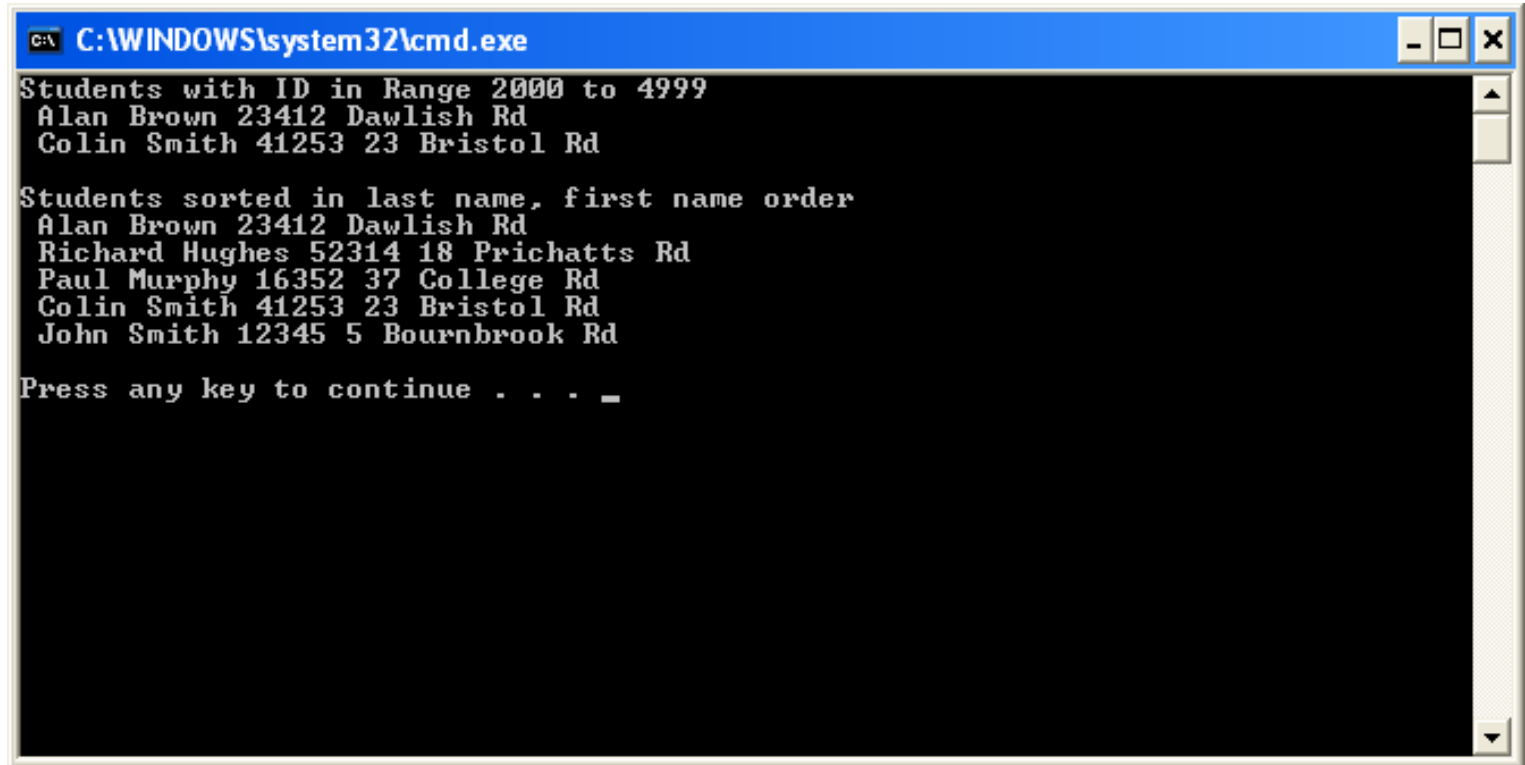
        // Order by last name and then first name
        var nameSorted =
            from s in students
            orderby s.LastName, s.FirstName
            select s;

        PrintArray(nameSorted, "Students sorted in last name, first name
                                order");
    }

    public static void PrintArray<T>(IEnumerable<T> arr, string message)
    {...}
}

```


Querying an array



```
C:\WINDOWS\system32\cmd.exe

Students with ID in Range 2000 to 4999
Alan Brown 23412 Dawlish Rd
Colin Smith 41253 23 Bristol Rd

Students sorted in last name, first name order
Alan Brown 23412 Dawlish Rd
Richard Hughes 52314 18 Prichatts Rd
Paul Murphy 16352 37 College Rd
Colin Smith 41253 23 Bristol Rd
John Smith 12345 5 Bournbrook Rd

Press any key to continue . . . _
```

Querying an array

- We can use LINQ to sort the array of *StudentInfo* objects by implementing the *IComparable* interface
 - We simply need to implement the *CompareTo()* method
 - If this isn't done when we try and sort an array of objects using LINQ, a runtime exception is generated

Querying an array

```
class StudentInfo : IComparable
{
    public StudentInfo(string ln, string fn, int id, string a)
    {
        lastName = ln; firstName = fn; idNumber = id; address = a;
    }

    public int CompareTo(object obj)
    {
        StudentInfo s = (StudentInfo)obj;

        if (s.ID < ID)
            return 1;
        else if (s.ID > ID)
            return -1;
        else
            return 0;
    }

    .
    .
    .
    .

    private string firstName,lastName;
    private int idNumber;
    private string address;
}
```

Querying an array

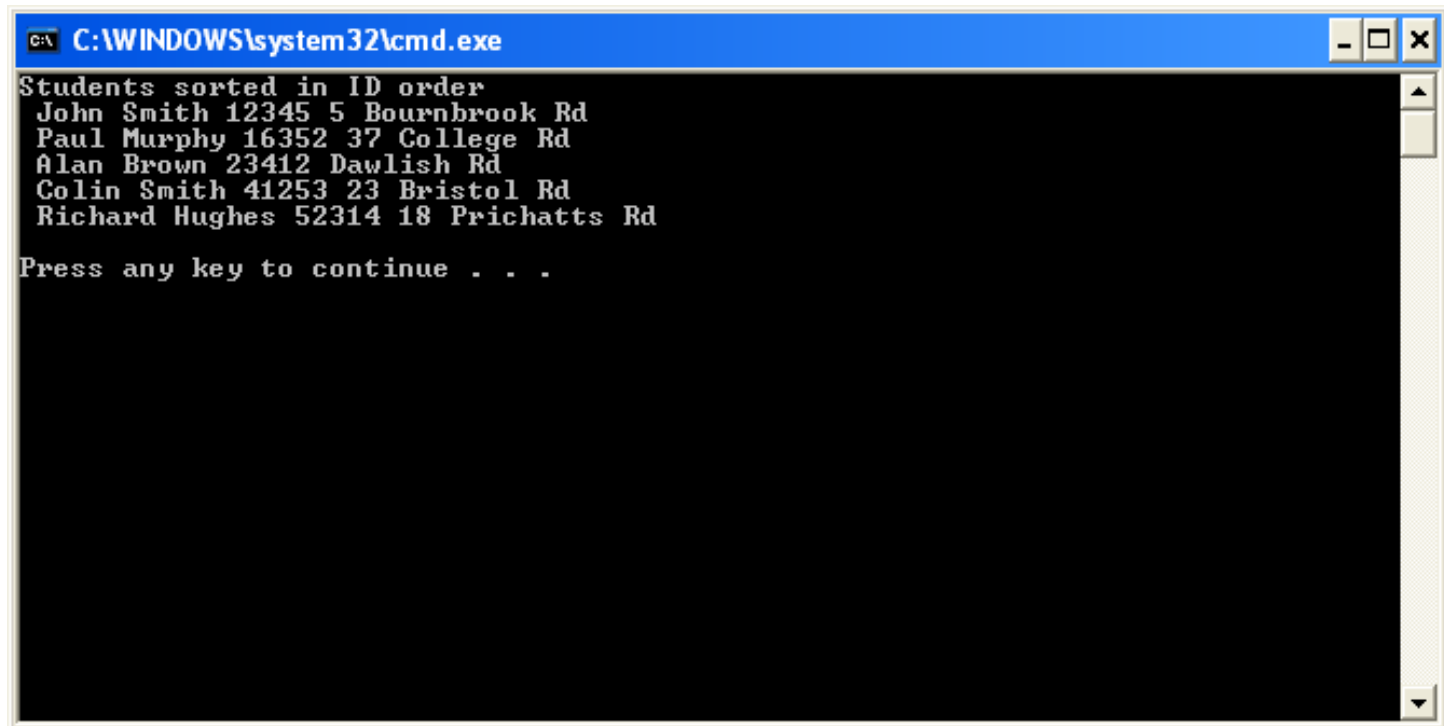
```
public class LINQtoObjectArray
{
    static void Main(string[] args)
    {
        StudentInfo[] students ={
            new StudentInfo("Smith", "John", 12345, "5 Bournbrook Rd"),
            new StudentInfo("Brown", "Alan", 23412, "Dawlish Rd"),
            new StudentInfo("Smith","Colin", 41253, "23 Bristol Rd"),
            new StudentInfo("Hughes", "Richard", 52314, "18 Prichatts Rd"),
            new StudentInfo("Murphy", "Paul", 16352, "37 College Rd") };

        // Order by ID
        var IDSorted =
            from s in students
            orderby s
            select s;

        PrintArray(IDSorted, "Students sorted in ID order");

        public static void PrintArray<T>(IEnumerable<T> arr, string message)
        {...}
    }
}
```

Querying an array



```
C:\WINDOWS\system32\cmd.exe
Students sorted in ID order
John Smith 12345 5 Bournbrook Rd
Paul Murphy 16352 37 College Rd
Alan Brown 23412 Dawlish Rd
Colin Smith 41253 23 Bristol Rd
Richard Hughes 52314 18 Prichatts Rd
Press any key to continue . . .
```

Querying an array

- LINQ defines a number of extension methods of *IEnumerable<T>*
 - Extension methods extend the functionality of *existing* classes (including classes in the FCL)
 - *Any()*
 - Checks to see if the container has any members
 - *Count()*
 - Returns a count of the number of members
 - *First(), Last()*
 - Returns the first and last members of the container
 - *Distinct()*
 - Removes duplicate members

```

public class LINQtoObjectArray
{
    static void Main(string[] args)
    {
        StudentInfo[] students = {
            new StudentInfo("Smith", "John", 12345, "5 Bournbrook Rd"),
            new StudentInfo("Brown", "Alan", 23412, "Dawlish Rd"),
            new StudentInfo("Smith", "Colin", 41253, "23 Bristol Rd"),
            new StudentInfo("Hughes", "Richard", 52314, "18 Prichatts Rd"),
            new StudentInfo("Murphy", "Paul", 16352, "37 College Rd") };

        // Order by last name and then first name
        var nameSorted =
            from s in students
            orderby s.LastName, s.FirstName
            select s;

        PrintArray(nameSorted, "Students sorted in last name, first name
            order");

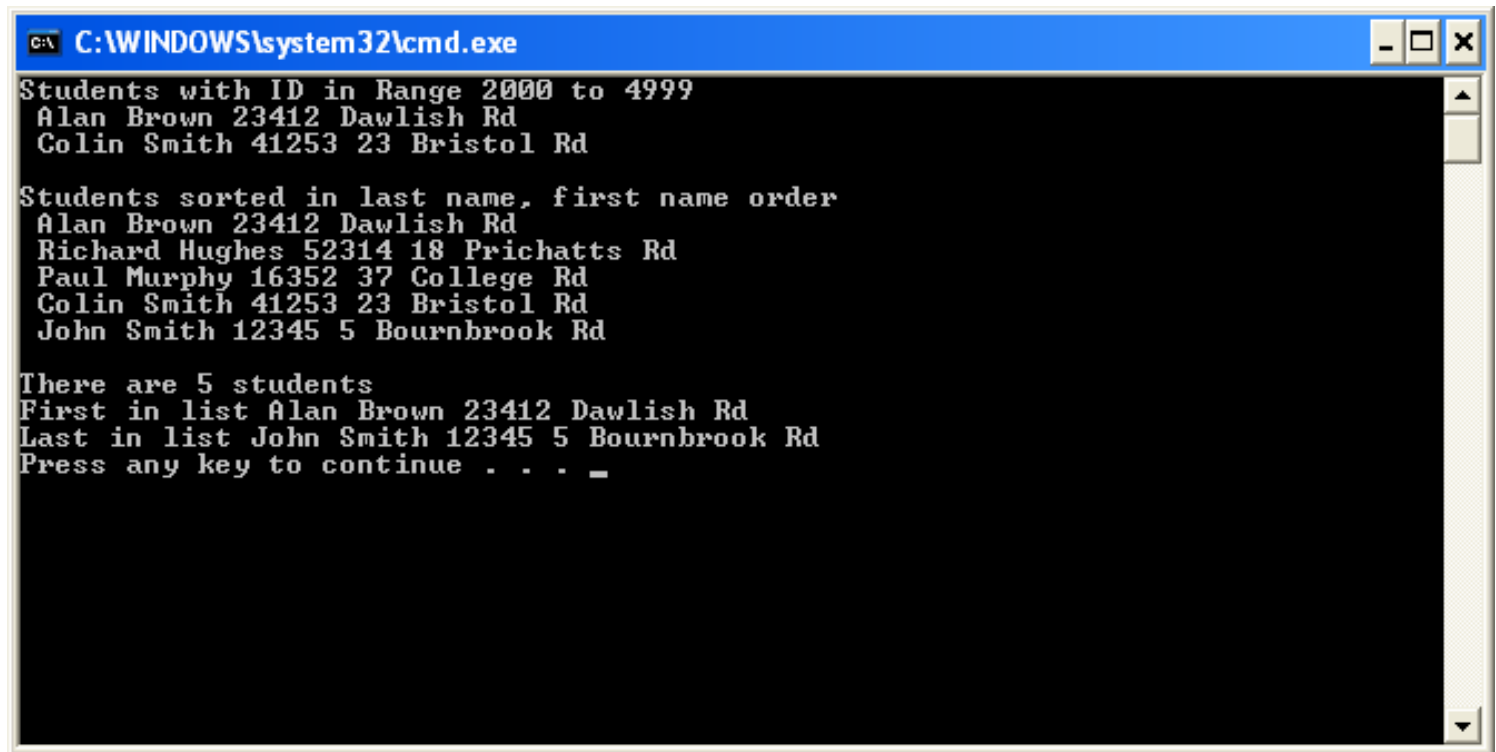
        Console.WriteLine("There are " + students.Count() + " students");

        if (nameSorted.Any())
        {
            Console.WriteLine("First in list " +
                nameSorted.First().ToString());

            Console.WriteLine("Last in list " +
                nameSorted.Last().ToString());
        }
    }
}

```

Querying an array



A screenshot of a Windows command prompt window. The title bar is blue and contains the text "C:\WINDOWS\system32\cmd.exe" and standard window control buttons (minimize, maximize, close). The command prompt has a black background with white text. The text displayed is as follows:

```
Students with ID in Range 2000 to 4999
Alan Brown 23412 Dawlish Rd
Colin Smith 41253 23 Bristol Rd

Students sorted in last name, first name order
Alan Brown 23412 Dawlish Rd
Richard Hughes 52314 18 Prichatts Rd
Paul Murphy 16352 37 College Rd
Colin Smith 41253 23 Bristol Rd
John Smith 12345 5 Bournbrook Rd

There are 5 students
First in list Alan Brown 23412 Dawlish Rd
Last in list John Smith 12345 5 Bournbrook Rd
Press any key to continue . . . _
```


Generic collections

- In our example programs so far we have already seen a *generic method* `PrintArray<T>`
 - This function outputs the string representation of the elements of an array
 - Its full declarations is :
 - `PrintArray<T>` takes any type which implements the `IEnumerable<T>` interface

```
public static void PrintArray<T>(IEnumerable<T> arr ,string message)
```

- Thus an `IEnumerable` object of any type can be passed to the method

Generic collections

- The compiler infers the type T from the actual call to `PrintArray<T>`

```
public class LINQtoObjectArray  
{  
    static void Main(string[] args)  
    {  
        StudentInfo[] students = {...};  
  
        // Order by last name and then first name  
        var nameSorted =  
            from s in students  
            orderby s.LastName, s.FirstName  
            select s;  
  
        // PrintArray<StudentInfo> called here  
  
        PrintArray(nameSorted, "Students sorted in last name, first name  
                                order");  
  
        .  
        .  
    }  
}
```

Generic collections

- Also the compiler determines whether the operations in the method body can be performed on any type the *T* represents

```
class MyClass
{
    public static void PrintArray(IEnumerable<int> arr, string message)
    {
        Console.Write("{0}",message);

        // Requires a ToString() override method for non built in types
        foreach (var element in arr)
            Console.Write(" {0}", element);

        Console.WriteLine();
    }
}
```

Generic collections

- Collections store groups of objects
- We are all familiar with arrays
 - Arrays don't resize dynamically but do so when the *Resize()* method is called
- The collection class *List<T>* dynamically resizes when objects are inserted
 - It's known as a generic class because real classes are instantiated by providing actual types in place of *T*
 - *List<int>*, *List<string>*, *List<StudentInfo>* etc

Generic collections

Method or property	Description
Add	Adds an element to the end of the List
Capacity	Property that gets or sets the number of elements a List can store
Clear	Removes all the elements from the List
Contains	Returns true if the List contains the specified element; otherwise, returns false
Count	Property that returns the number of elements stored in the List
IndexOf	Returns the index of the first occurrence of the specified value in the List
Insert	Inserts an element at the specified index
Remove	Removes the first occurrence of the specified value
RemoveAt	Removes the element at the specified index
RemoveRange	Removes a specified number of elements starting at a specified index
Sort	Sorts the List
TrimExcess	Sets the Capacity of the List to the number of elements the List currently contains (Count)

Generic collections

- We can create a list of *StudentInfo* objects and add items (to the end of the list) and insert items (anywhere in the list)
- We can display the list using exactly the same generic function as for displaying an array
- We could manipulate the list using the methods shown in the table

```

public class LINQtoList
{
    static void Main(string[] args)
    {
        StudentInfo[] students ={
            new StudentInfo("Smith", "John", 12345, "5 Bournbrook Rd"),
            new StudentInfo("Brown", "Alan", 23412, "Dawlish Rd"),
            new StudentInfo("Smith", "Colin", 41253, "23 Bristol Rd"),
            new StudentInfo("Hughes", "Richard", 52314, "18 Prichatts Rd"),
            new StudentInfo("Murphy", "Paul", 16352, "37 College Rd") };

        List<StudentInfo> studentList = new List<StudentInfo>();

        studentList.Add(students[0]);
        studentList.Add(students[1]);
        studentList.Add(students[2]);

        studentList.Insert(2, students[3]);

        PrintList(studentList, "Student list:");
    }

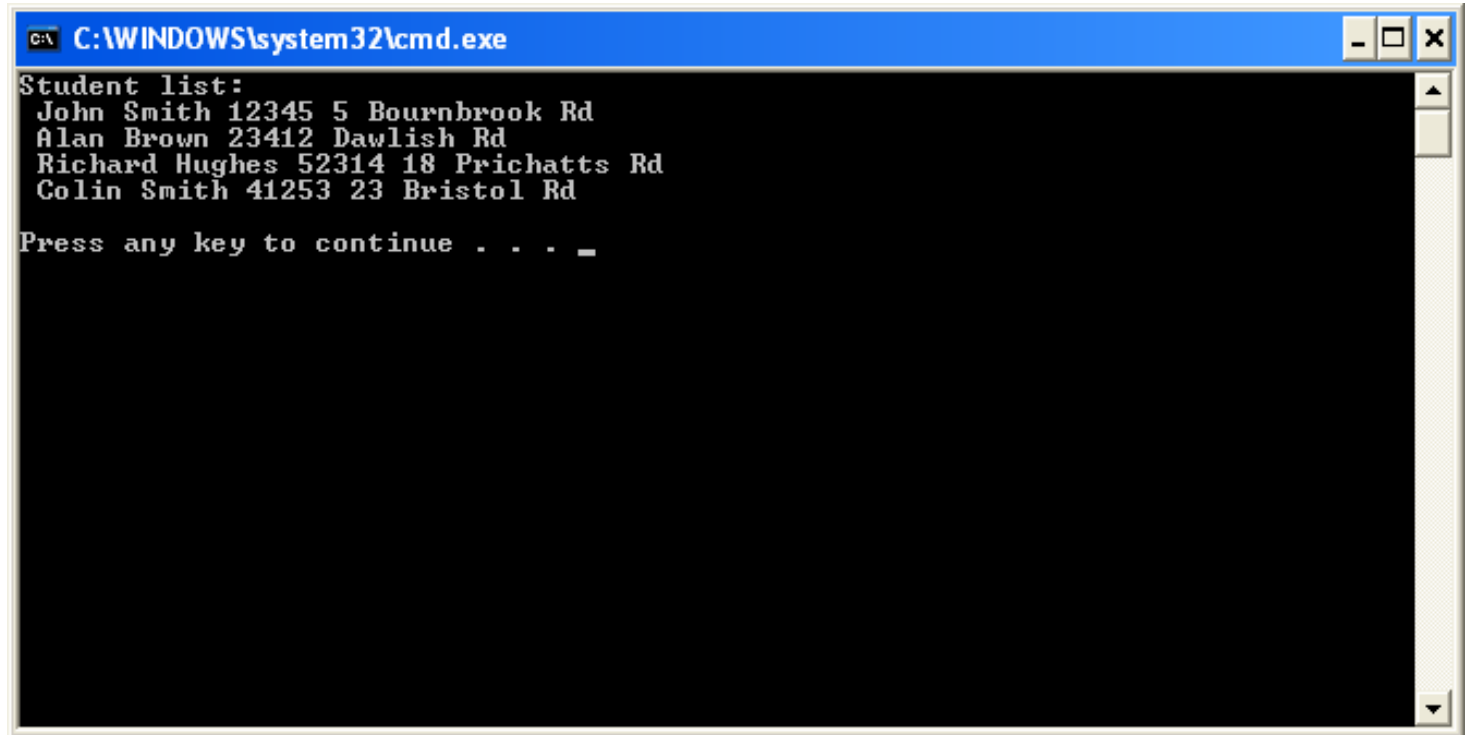
    public static void PrintList<T>(IEnumerable<T> arr, string message)
    {
        Console.WriteLine("{0}", message);

        foreach (T element in arr)
            Console.WriteLine(" {0}", element);

        Console.WriteLine();
    }
}

```

Generic collections



```
C:\WINDOWS\system32\cmd.exe
Student list:
John Smith 12345 5 Bournbrook Rd
Alan Brown 23412 Dawlish Rd
Richard Hughes 52314 18 Prichatts Rd
Colin Smith 41253 23 Bristol Rd
Press any key to continue . . . _
```


Querying a generic collection

- LINQ to Objects can query lists (and any other collection) in much the same way as querying an array
- For example, we could sort our list of students after first converting their surnames into upper case
 - The query makes use of the *let* clause which creates a new range variable
 - Enables a temporary result to be stored for later use in the query

```

public class LINQtoList
{
    static void Main(string[] args)
    {
        StudentInfo[] students = {
            new StudentInfo("Smith", "John", 12345, "5 Bournbrook Rd"),
            new StudentInfo("Brown", "Alan", 23412, "Dawlish Rd"),
            new StudentInfo("Smith", "Colin", 41253, "23 Bristol Rd"),
            new StudentInfo("Hughes", "Richard", 52314, "18 Prichatts Rd"),
            new StudentInfo("Murphy", "Paul", 16352, "37 College Rd") };

        List<StudentInfo> studentList = new List<StudentInfo>();

        studentList.Add(students[0]);
        studentList.Add(students[1]);
        studentList.Add(students[2]);

        studentList.Insert(2, students[3]);

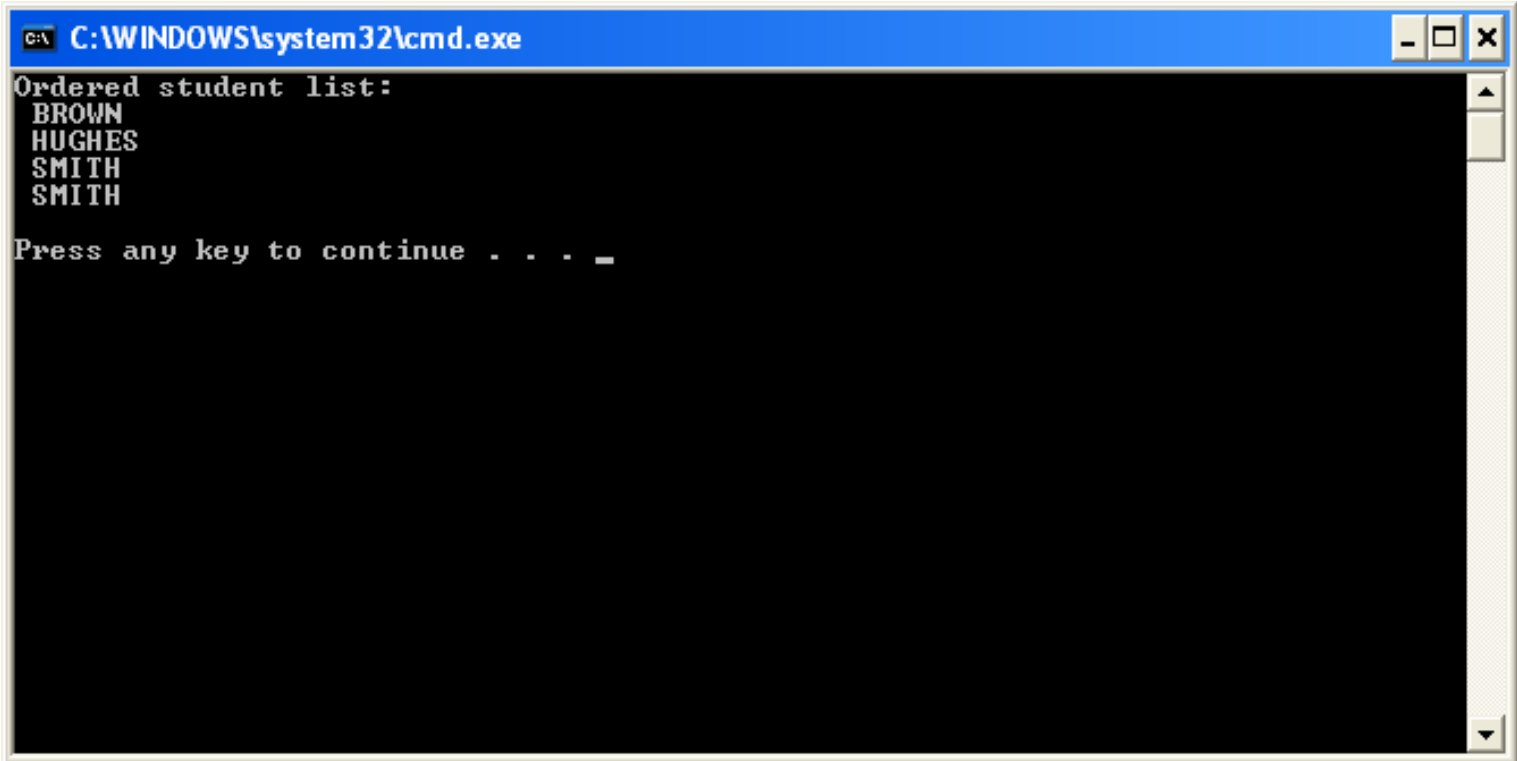
        var orderedUpperCaseList =
            from student in studentList
            let upperCaseName = student.LastName.ToUpper()
            orderby upperCaseName
            select upperCaseName;

        PrintList(orderedUpperCaseList, "Ordered student list:");
    }

    public static void PrintList<T>(IEnumerable<T> arr, string message)
    {...}
}

```

Querying a generic collection



```
C:\WINDOWS\system32\cmd.exe
Ordered student list:
BROWN
HUGHES
SMITH
SMITH
Press any key to continue . . . _
```

By
Dr. Mike Spann