Delegates, events and Linq

Lambdas

- A lambda expression uses a shorter notation to create a function/method.
- The function is anonymous and is often provided inline.
- Used in combination with delegates
- Relies heavily on type inference

```
bool Filter(int number)
{
        return number%2 == 0;
}
```

```
number => number%2 == 0;
```

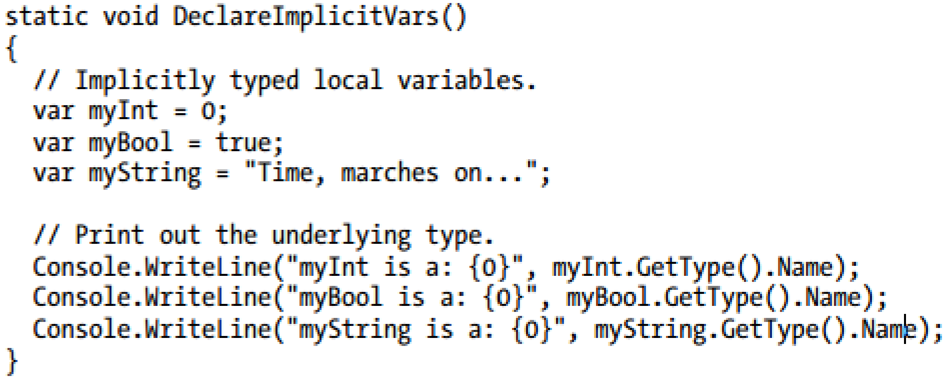
Lab 7

LINQ-Specific Programming Constructs

- LINQ is basically a strongly-typed query language directly embedded in C#
  - Look and feel of LINQ queries is similar to SQL statements
  - LINQ can be applied to all kinds of data stores
  - Note: the syntax is not identical!
    - Often, it's the opposite of a SQL query
    - It's similar, nothing more!
- To work, a lot of new things had to be added to C# and VB with .NET 3.5
  - Implicitly typed local variables
  - Object/collection initialization syntax
  - Lambda expressions
  - Extension methods

Implicit Typing of Local Variables

- The var keyword is the key here!
  - Allows you to define a local variable without explicitly specifying the underlying data type
  - Is however, is strongly typed, as the compiler will determine the correct data type based on the initial assignm

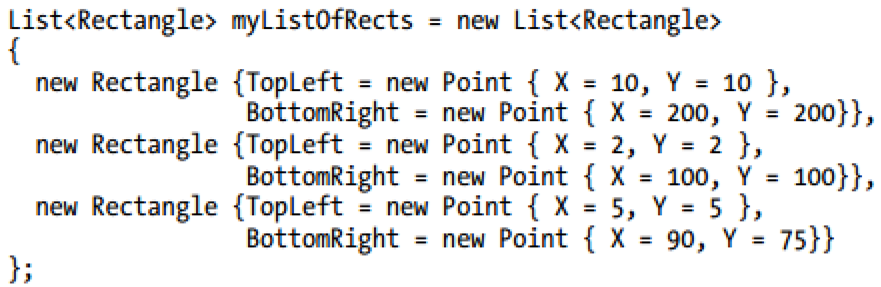


```
static void DeclareImplicitVars()
{
  // Implicitly typed local variables.
  var myInt = 0;
  var myBool = true;
  var myString = "Time, marches on...";

  // Print out the underlying type.
  Console.WriteLine("myInt is a: {0}", myInt.GetType().Name);
  Console.WriteLine("myBool is a: {0}", myBool.GetType().Name);
  Console.WriteLine("myString is a: {0}", myString.GetType().Name);
}
```

- Almost mandatory to use when using LINQ
  - LINQ queries will return a sequence of data types, which are not known until compile time
    - Impossible to declare a variable type!

Object and Collection Initialization Syntax

- Object initialization syntax allows you to create a class or structure variable, and set any number of its public properties, in one go
  - Compact and easy-to-read syntax to create your objects
- Also available for collections

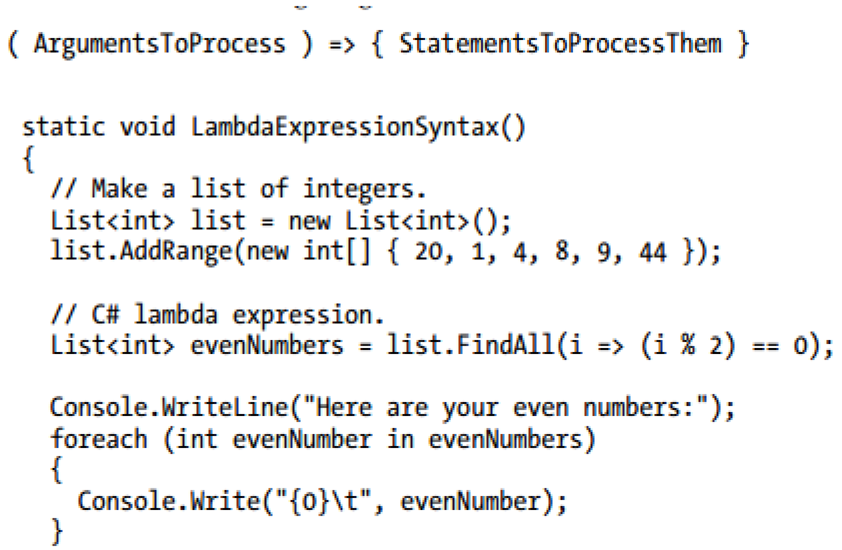


```
List<Rectangle> myListOfRects = new List<Rectangle>
{
  new Rectangle {TopLeft = new Point { X = 10, Y = 10 },
                 BottomRight = new Point { X = 200, Y = 200}},
  new Rectangle {TopLeft = new Point { X = 2, Y = 2 },
                 BottomRight = new Point { X = 100, Y = 100}},
  new Rectangle {TopLeft = new Point { X = 5, Y = 5 },
                 BottomRight = new Point { X = 90, Y = 75}}
};
```

- Not a requirement to use but code will be more compact
- Is also needed to be able to declare anonymous types

Lambda Expressions

- The => operator enables lambda expressions
  - Can be used instead of creating delegate or anonymous methods
  - Much less code has to be written

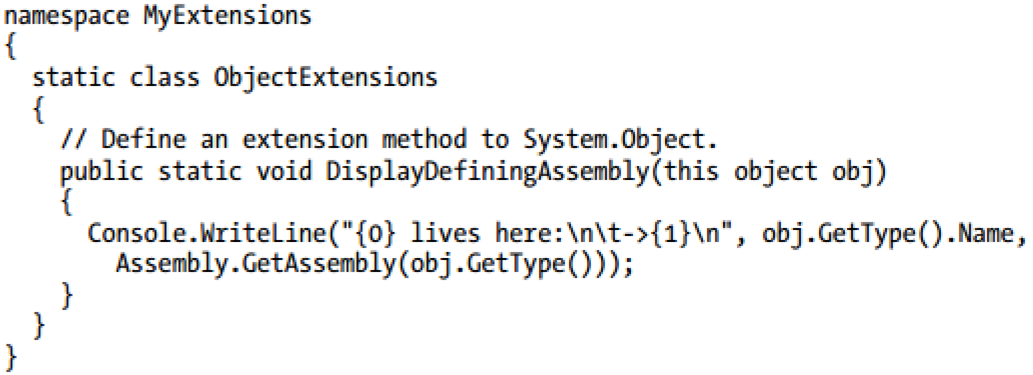


```
( ArgumentsToProcess ) => { StatementsToProcessThem }

 static void LambdaExpressionSyntax()
 {
   // Make a list of integers.
   List<int> list = new List<int>();
   list.AddRange(new int[] { 20, 1, 4, 8, 9, 44 });

   // C# lambda expression.
   List<int> evenNumbers = list.FindAll(i => (i % 2) == 0);

   Console.WriteLine("Here are your even numbers:");
   foreach (int evenNumber in evenNumbers)
   {
     Console.Write("{0}\t", evenNumber);
   }
```

- LINQ operators are shorthand for calling methods on System.Linq.Enumerable<T>

Extension methods

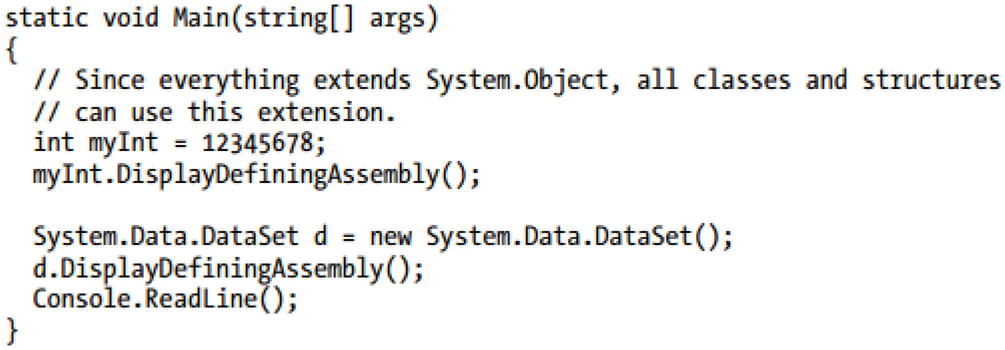
- Extension methods allow us to add more functionality on a type without the need for subclasses
    - Even works on sealed classes and structures
        - These can’t be subclassed!
- First parameter is the this keyword
    - Indicates which type we’re extending
- Must be defined in a static class as a static method



```
namespace MyExtensions
{
  static class ObjectExtensions
  {
    // Define an extension method to System.Object.
    public static void DisplayDefiningAssembly(this object obj)
    {
      Console.WriteLine("{0} lives here:\n\t->{1}\n", obj.GetType().Name,
        Assembly.GetAssembly(obj.GetType()));
    }
  }
}
```

Extension methods

- To use this extension method, we must import the namespace that contains the extension method

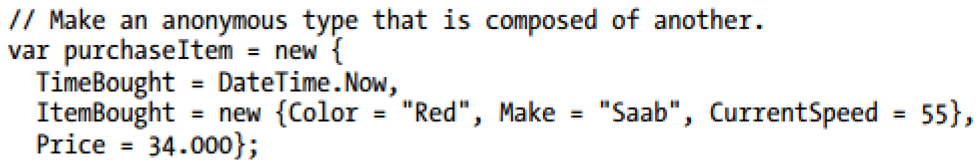


```
static void Main(string[] args)
{
    // Since everything extends System.Object, all classes and structures
    // can use this extension.
    int myInt = 12345678;
    myInt.DisplayDefiningAssembly();

    System.Data.DataSet d = new System.Data.DataSet();
    d.DisplayDefiningAssembly();
    Console.ReadLine();
}
```

- LINQ itself is all about using built-in extension methods
    - Each LINQ operator is shorthand for a call to an underlying extension method defined in System.Linq.Enumerable classes

Anonymous Types

- Allows us to quickly shape data that's not used often
  - Instead of creating a class ourselves, we let the compiler create one quickly at compile time
  - Uses a set of key/value pairs



```
// Make an anonymous type that is composed of another.
var purchaseItem = new {
  TimeBought = DateTime.Now,
  ItemBought = new {Color = "Red", Make = "Saab", CurrentSpeed = 55},
  Price = 34.000};
```

- When using LINQ, we'll often use anonymous types ourselves
  - LINQ projections

Understanding the Role of LINQ

- LINQ API is an attempt to provide a consistent, symmetrical manner in which programmers can obtain and manipulate “data” in the broad sense of the term
  - With LINQ, we can create query expressions in the language itself
  - These are similar to SQL queries
- Query expressions can be used to interact with numerous types of data
  - Not all relational!
- There are different flavors of LINQ but they all work in the same way

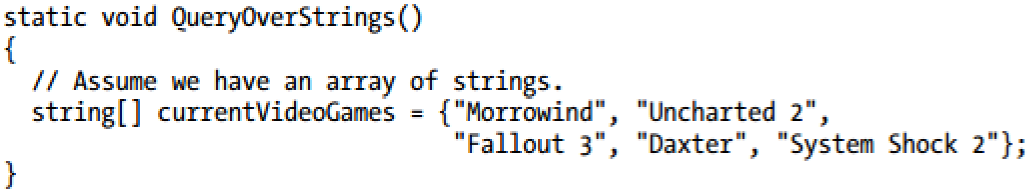
LINQ and Extension Methods

- LINQ is a set of extension methods on IEnumerable<T> covered with some syntactic sugar.

  - Roland

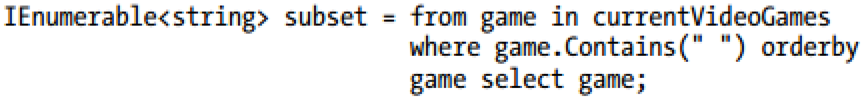
Applying LINQ Queries to Primitive Arrays

- We’ll start with LINQ to objects on a array



```
static void QueryOverStrings()
{
  // Assume we have an array of strings.
  string[] currentVideoGames = {"Morrowind", "Uncharted 2",
                                "Fallout 3", "Daxter", "System Shock 2"};
}
```

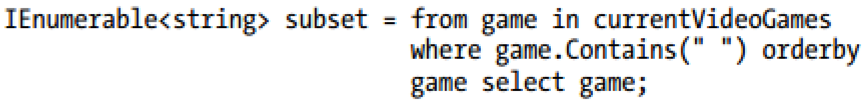
- Assume we want the items without spaces or with a number
  - Can be done without LINQ but will be quite “dirty”
- With LINQ, this becomes much easier
  - All with space in alphabetical order
  - Uses from, in where…
  - Easy to read
  - g is just a name
    - Could be anything



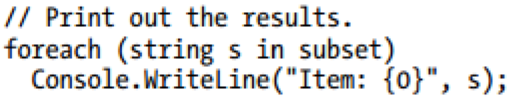
```
IEnumerable<string> subset = from game in currentVideoGames
                             where game.Contains(" ") orderby
                             game select game;
```

Applying LINQ Queries to Primitive Arrays

- Once we have the results in subset, we can then loop over the results



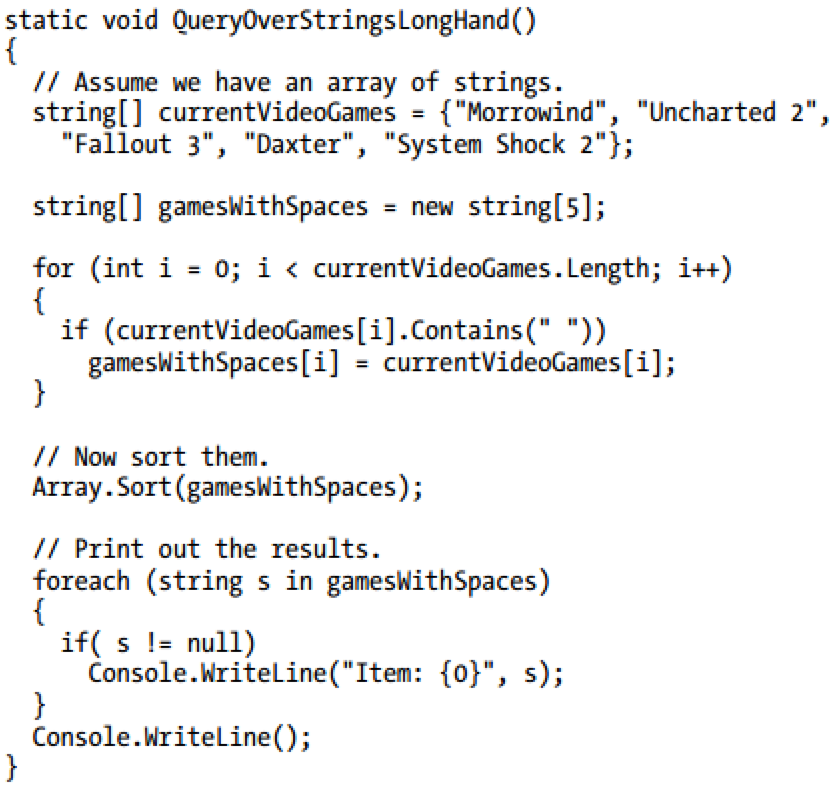
```
IEnumerable<string> subset = from game in currentVideoGames
                             where game.Contains(" ") orderby
                             game select game;
```



```
// Print out the results.
foreach (string s in subset)
  Console.WriteLine("Item: {0}", s);
```

It’s all possible without LINQ!

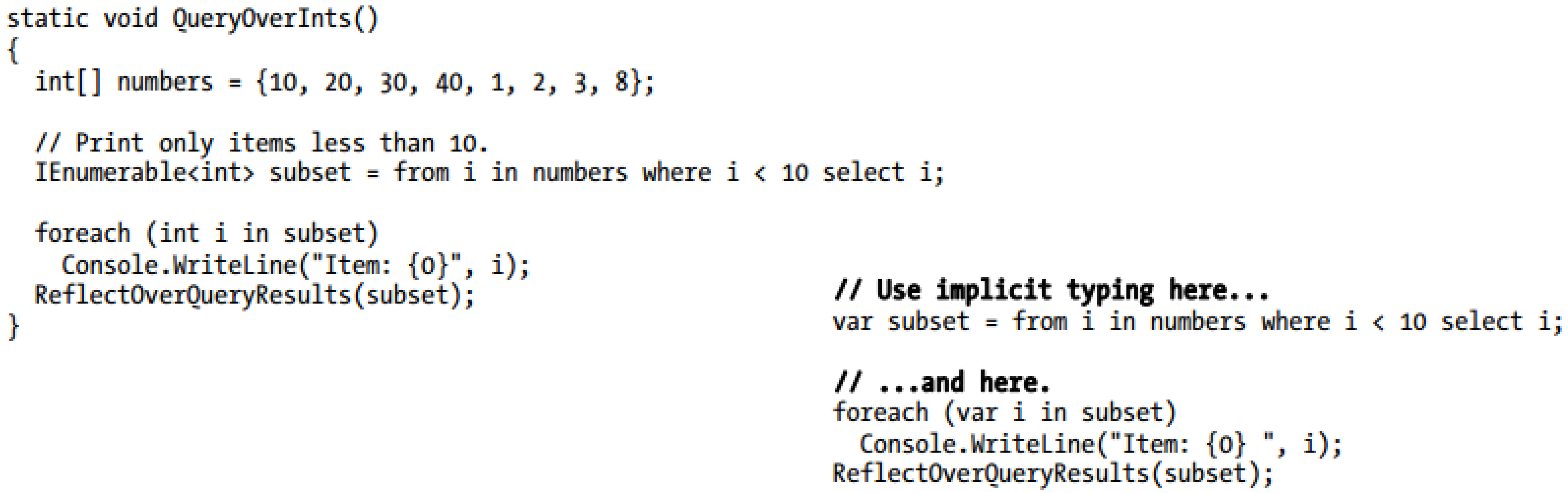
- All you can do with LINQ can be done without it as well
  - Loops, ifs…
  - LINQ just makes things easier to write and read!



```
static void QueryOverStringsLongHand()
{
  // Assume we have an array of strings.
  string[] currentVideoGames = {"Morrowind", "Uncharted 2",
    "Fallout 3", "Daxter", "System Shock 2"};

  string[] gamesWithSpaces = new string[5];

  for (int i = 0; i < currentVideoGames.Length; i++)
  {
    if (currentVideoGames[i].Contains(" "))
      gamesWithSpaces[i] = currentVideoGames[i];
  }

  // Now sort them.
  Array.Sort(gamesWithSpaces);

  // Print out the results.
  foreach (string s in gamesWithSpaces)
  {
    if( s != null)
      Console.WriteLine("Item: {0}", s);
  }
  Console.WriteLine();
}
```

LINQ and Implicitly Typed Local Variables

- In the previous example, the type of the result was still pretty easy
  - Would be tedious to write a new type for all results we’re getting back from a LINQ query
  - Might be even so that the type doesn’t even exist before compile time!



```
static void QueryOverInts()
{
  int[] numbers = {10, 20, 30, 40, 1, 2, 3, 8};

  // Print only items less than 10.
  IEnumerable<int> subset = from i in numbers where i < 10 select i;

  foreach (int i in subset)
    Console.WriteLine("Item: {0}", i);
  ReflectOverQueryResults(subset);
}
```

```
// Use implicit typing here...
var subset = from i in numbers where i < 10 select i;

// ...and here.
foreach (var i in subset)
  Console.WriteLine("Item: {0} ", i);
ReflectOverQueryResults(subset);
```

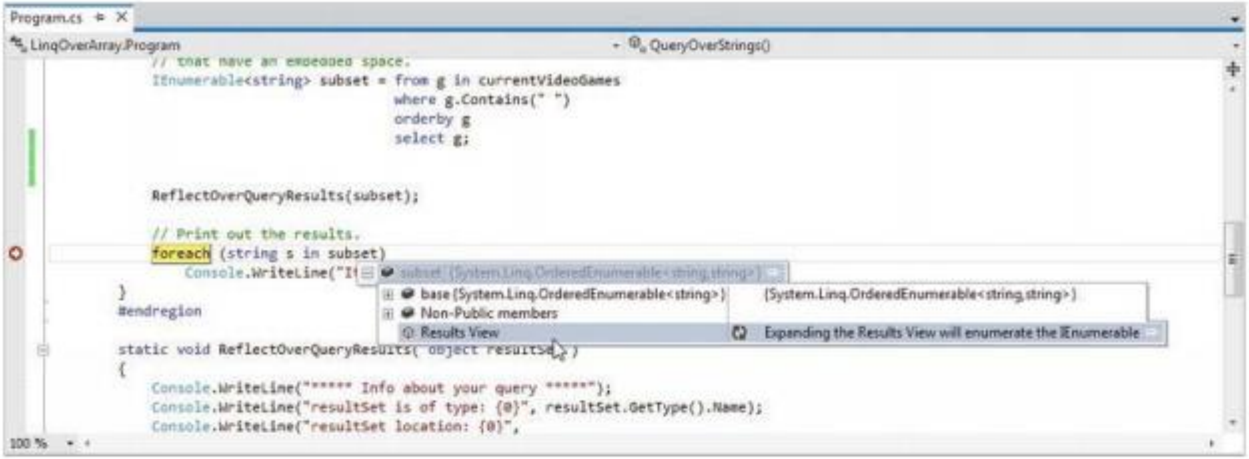
  - Here it’s an IEnumerable<T>, but underlying, it’s another low-level class that gets returned

The Role of Deferred Execution

- A very important note: LINQ query expressions are not actually evaluated until you iterate over the sequence
  - Deferred execution
  - Allows us to create several queries on the same container and still get back only the latest results

The Role of Deferred Execution

- Visual Studio allows us to trigger the execution of the expression
  - Click on the Results View



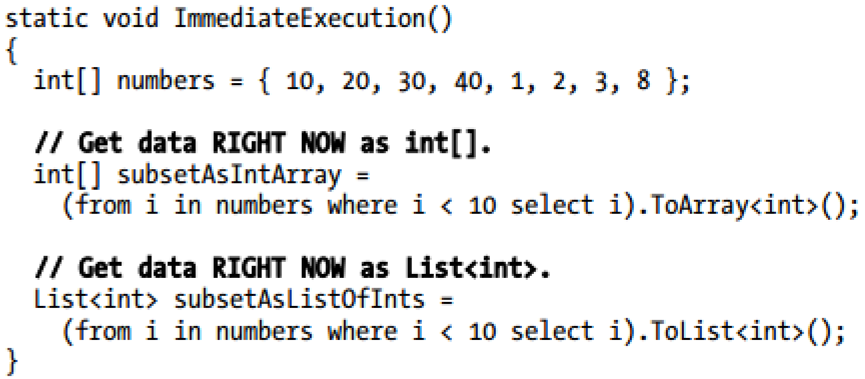
```
            // that have an embedded space.
            IEnumerable<string> subset = from g in currentVideoGames
                                         where g.Contains(" ")
                                         orderby g
                                         select g;


            ReflectOverQueryResults(subset);

            // Print out the results.
            foreach (string s in subset)
                Console.WriteLine("It
        }
        #endregion

        static void ReflectOverQueryResults( object resultSet )
        {
            Console.WriteLine("***** Info about your query *****");
            Console.WriteLine("resultSet is of type: {0}", resultSet.GetType().Name);
            Console.WriteLine("resultSet location: {0}",
```

subset {System.Linq.OrderedEnumerable<string,string>}

base {System.Linq.OrderedEnumerable<string>}	{System.Linq.OrderedEnumerable<string,string>}
Non-Public members	
Results View	Expanding the Results View will enumerate the IEnumerable

The Role of Immediate Execution

- When we need access to the results from code, we can call another extension method
  - ToArray<T>()
  - ToDictionary<TSource,TKey>()
  - ToList<T>()
- Cause the LINQ query to be executed at that point in time
  - If data changes, we don’t see that in the result set
  - We get a snapshot of the data

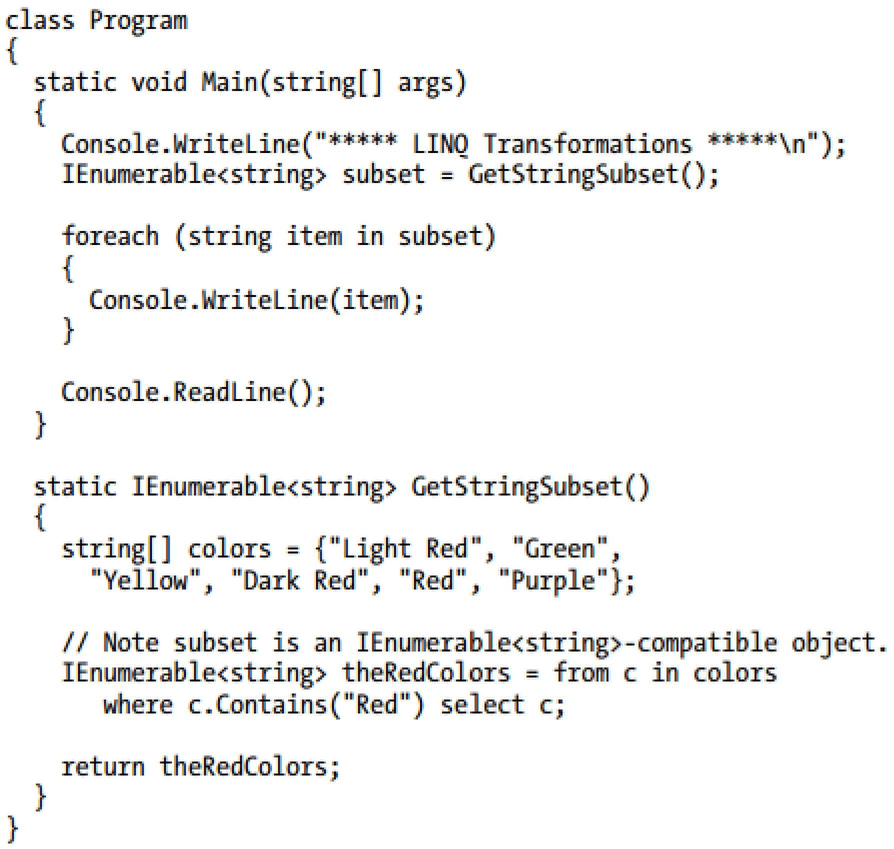


```
static void ImmediateExecution()
{
  int[] numbers = { 10, 20, 30, 40, 1, 2, 3, 8 };

  // Get data RIGHT NOW as int[].
  int[] subsetAsIntArray =
    (from i in numbers where i < 10 select i).ToArray<int>();

  // Get data RIGHT NOW as List<int>.
  List<int> subsetAsListOfInts =
    (from i in numbers where i < 10 select i).ToList<int>();
}
```

Returning the Result of a LINQ Query

- It is possible to define a field within a class (or structure) whose value is the result of a LINQ query
  - However, you cannot make use of implicit typing (as the var keyword cannot be used for fields) and the target of the LINQ query cannot be instance-level data
- LINQ queries are defined (almost always) in a method or a property
  - Result is stored in a var
  - But we can't create var on fields
- Returning the result is therefore always using IEnumerable<T>

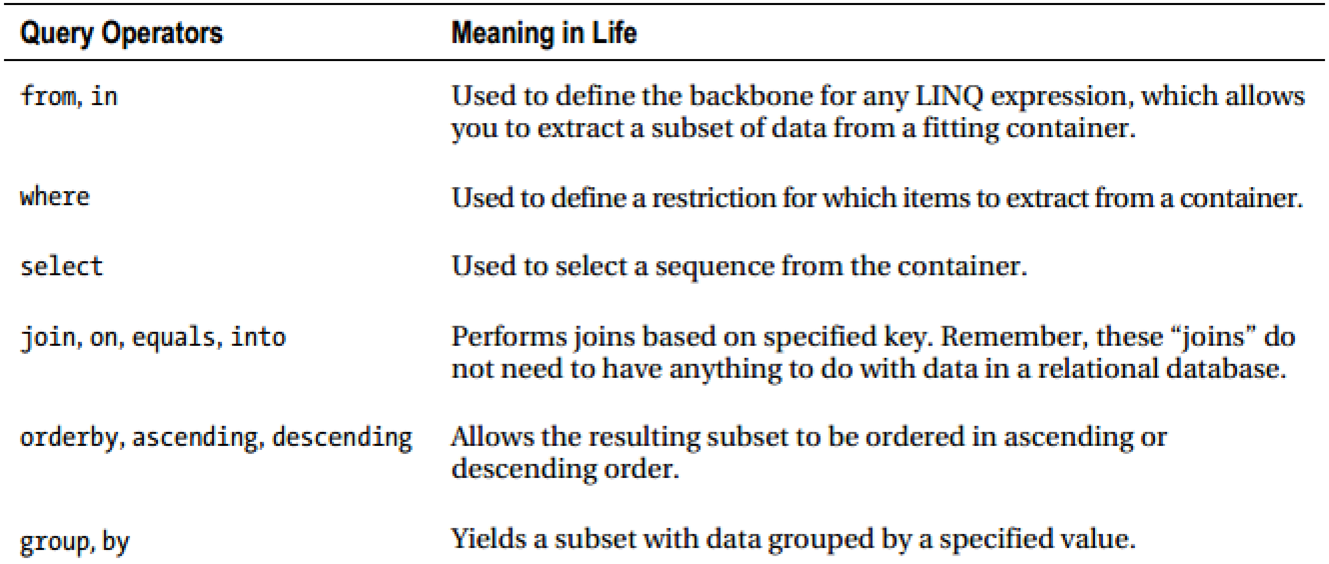
Returning the Result of a LINQ Query



```
class Program
{
  static void Main(string[] args)
  {
    Console.WriteLine("***** LINQ Transformations *****\n");
    IEnumerable<string> subset = GetStringSubset();

    foreach (string item in subset)
    {
      Console.WriteLine(item);
    }

    Console.ReadLine();
  }

  static IEnumerable<string> GetStringSubset()
  {
    string[] colors = {"Light Red", "Green",
      "Yellow", "Dark Red", "Red", "Purple"};

    // Note subset is an IEnumerable<string>-compatible object.
    IEnumerable<string> theRedColors = from c in colors
       where c.Contains("Red") select c;

    return theRedColors;
  }
}
```

LINQ syntax

- C# has a quite a few LINQ operators
- Most commonly used ones



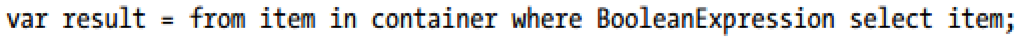
Query Operators	Meaning in Life
from, in	Used to define the backbone for any LINQ expression, which allows you to extract a subset of data from a fitting container.
where	Used to define a restriction for which items to extract from a container.
select	Used to select a sequence from the container.
join, on, equals, into	Performs joins based on specified key. Remember, these "joins" do not need to have anything to do with data in a relational database.
orderby, ascending, descending	Allows the resulting subset to be ordered in ascending or descending order.
group, by	Yields a subset with data grouped by a specified value.

LINQ syntax

- Next to that, LINQ has a large number of extension methods as well for which there’s no direct operator
  - Reverse<>(), ToArray<>(), ToList<>()
  - Distinct<>(), Union<>(), Intersect<>()
  - Count<>(), Sum<>(), Min<>(), Max<>()
  - …

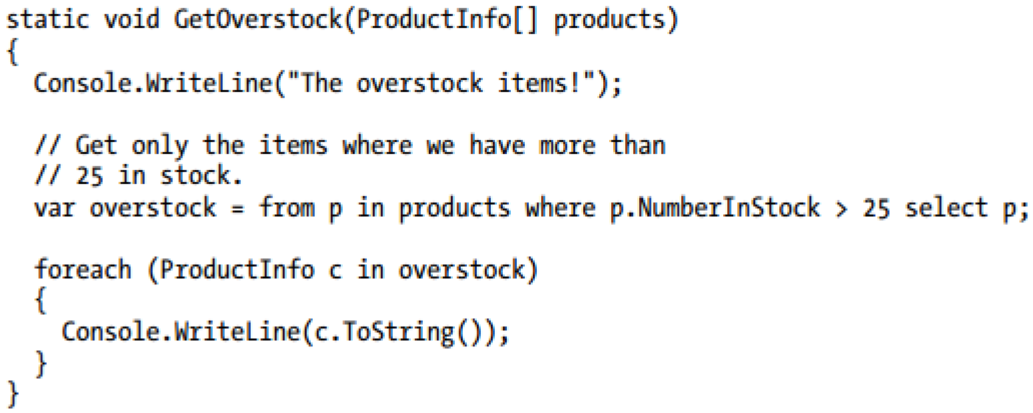
Obtaining Subsets of Data

- To obtain a specific subset from a container, you can make use of the where operator

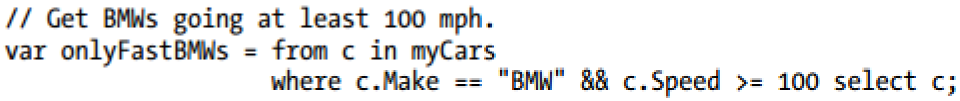


```
var result = from item in container where BooleanExpression select item;
```

  - Where expects an expression that evaluates to a Boolean



```
static void GetOverstock(ProductInfo[] products)
{
  Console.WriteLine("The overstock items!");

  // Get only the items where we have more than
  // 25 in stock.
  var overstock = from p in products where p.NumberInStock > 25 select p;

  foreach (ProductInfo c in overstock)
  {
    Console.WriteLine(c.ToString());
  }
}
```

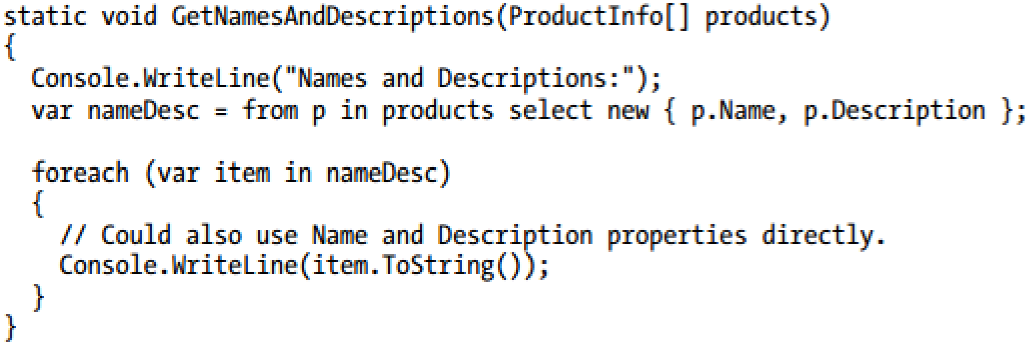


```
// Get BMWs going at least 100 mph.
var onlyFastBMWs = from c in myCars
                   where c.Make == "BMW" && c.Speed >= 100 select c;
```

  - In the where clause, we can use any C# operator

Projecting New Data Types

- It is also possible to project new forms of data from an existing data source
  - Take an existing item and create a new one
  - Can be done in combination with anonymous types

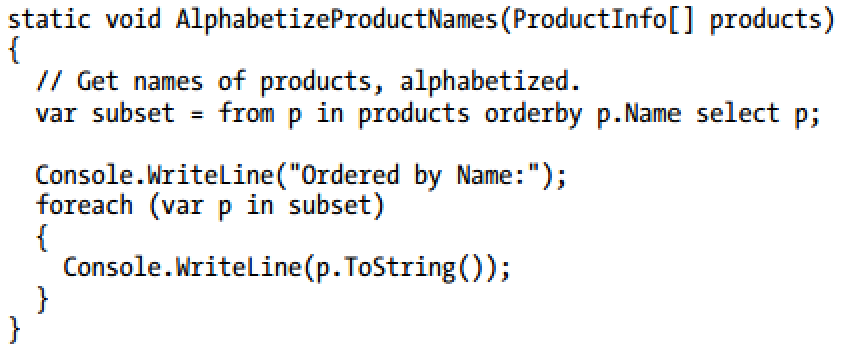


```
static void GetNamesAndDescriptions(ProductInfo[] products)
{
  Console.WriteLine("Names and Descriptions:");
  var nameDesc = from p in products select new { p.Name, p.Description };

  foreach (var item in nameDesc)
  {
    // Could also use Name and Description properties directly.
    Console.WriteLine(item.ToString());
  }
}
```

  - Here var is required: this type is only known at compile time
    - Can’t be used as return value this way
      - Transform using immediate execution if needed (ToArray)

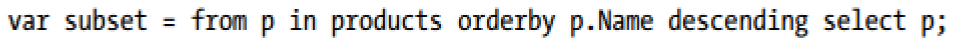
Sorting Expressions

- A query expression can take an orderby operator to sort items in the subset by a specific value
  - Order is ascending by default
    - Alphabetical, numerical starting at 0



```
static void AlphabetizeProductNames(ProductInfo[] products)
{
  // Get names of products, alphabetized.
  var subset = from p in products orderby p.Name select p;

  Console.WriteLine("Ordered by Name:");
  foreach (var p in subset)
  {
    Console.WriteLine(p.ToString());
  }
}
```

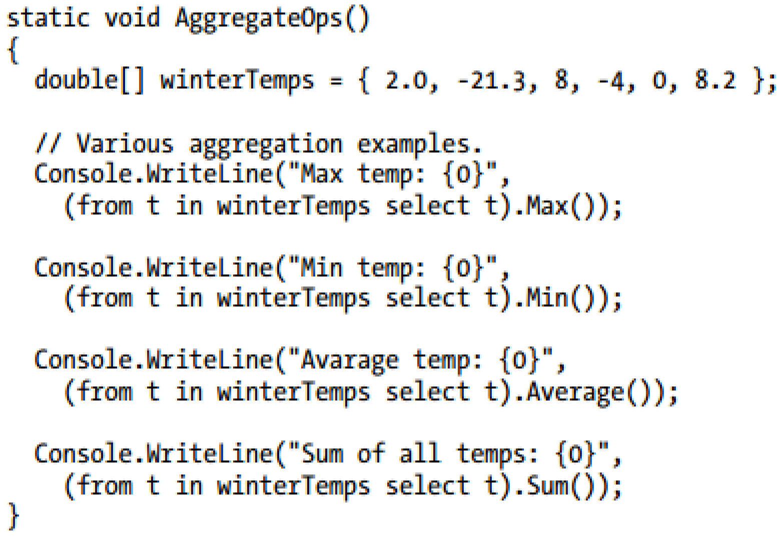
  - Can be specified to be descending



```
var subset = from p in products orderby p.Name descending select p;
```

LINQ Aggregation Operations

- LINQ queries can also be designed to perform various aggregation operations on the result set
  - Count()
  - Min()
  - Max()
  - Average()



```
static void AggregateOps()
{
  double[] winterTemps = { 2.0, -21.3, 8, -4, 0, 8.2 };

  // Various aggregation examples.
  Console.WriteLine("Max temp: {0}",
    (from t in winterTemps select t).Max());

  Console.WriteLine("Min temp: {0}",
    (from t in winterTemps select t).Min());

  Console.WriteLine("Avarage temp: {0}",
    (from t in winterTemps select t).Average());

  Console.WriteLine("Sum of all temps: {0}",
    (from t in winterTemps select t).Sum());
}
```

Practicing LINQ

- Create a collection of a simple type (e.g. List<int>) containing some values.
- Experiment with the myriad of LINQ methods available on the collection. For example:
  - Count
  - Where, Select
  - Min, Max, Average

- Now create a collection of a complex type (some class with properties)
- Repeat the experiments.