

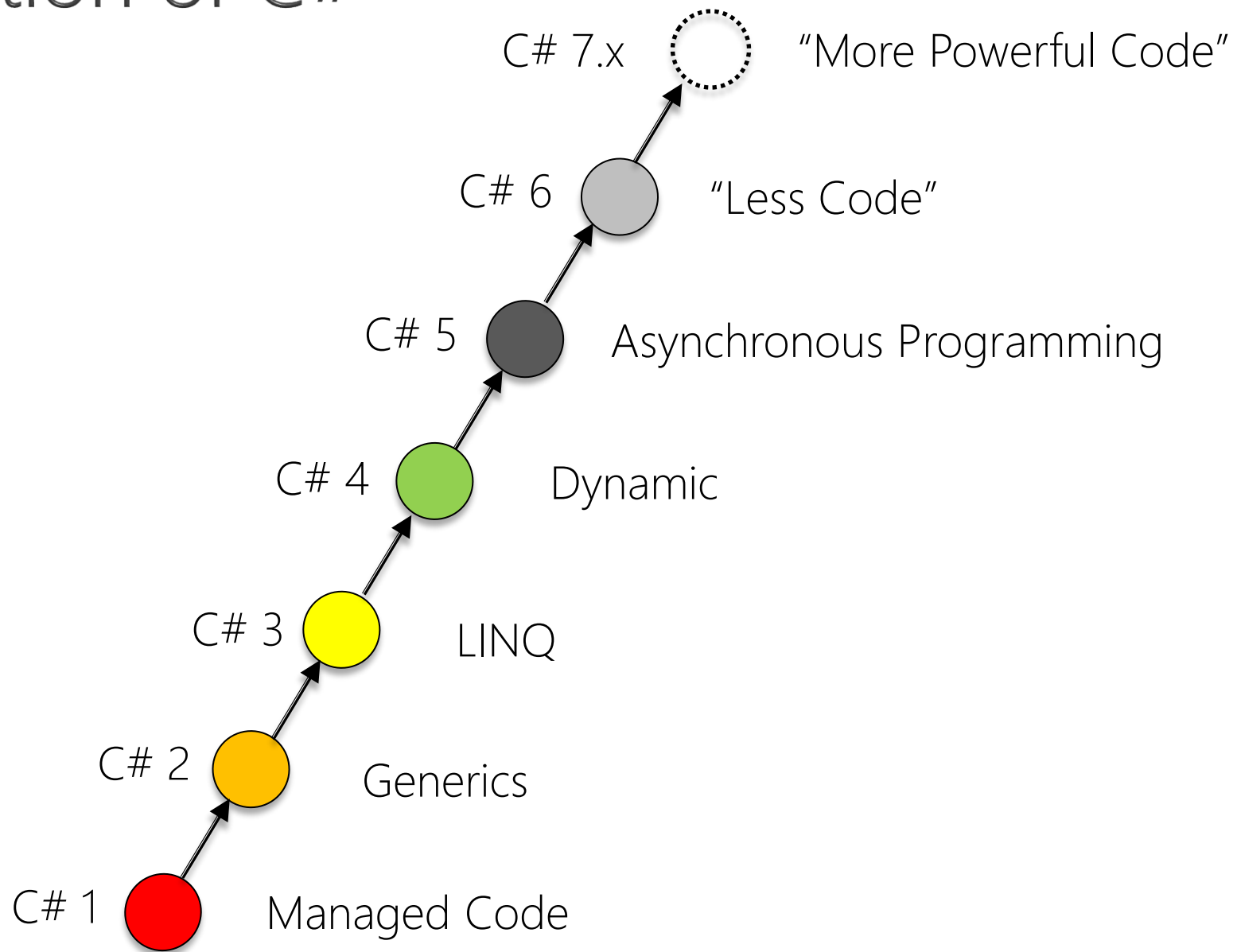
Module 01:

"Recapping
C# 7.0, 7.1, 7.2, and 7.3"



TEKNOLOGISK
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Evolution of C#



Agenda

- ▶ Introduction
- ▶ **Value Tuples and Syntax**
- ▶ Pattern Matching
- ▶ Method Improvements
- ▶ Expression Improvements
- ▶ Other C# 7.1 Additions
- ▶ Other C# 7.2 Additions
- ▶ Other C# 7.3 Additions

Introducing Tuples

- ▶ Not the **Tuple<T1,T2>** type already in .NET 4.0
 - Instead it is a value type with dedicated syntax

```
(int, int) FindVowels( string s )  
{  
    int v = 0;  
    int c = 0;  
    foreach (char letter in s)  
    {  
        ...  
    }  
    return (v, c);  
}
```

```
string input = ReadLine();
```

```
var t = FindVowels(input);
```

```
WriteLine($"There are {t.Item1} vowels and  
{t.Item2} consonants in \"{input}\"");
```

Syntax, Literals, and Conversions

- ▶ Can be easily converted / deconstructed to other names

```
var (vowels, cons) = FindVowels(input);  
(int vowels, int cons) = FindVowels(input);
```

```
WriteLine($"There are {vowels} vowels and {cons} consonants in ... ");
```

```
(int vowels, int cons) FindVowels( string s )  
{  
    var tuple = (v: 0, c: 0);  
    ...  
    return tuple;  
}
```

- ▶ Tuples can be supplied with descriptive names
- ▶ Mutable and directly addressable
- ▶ Built-in: `ToString()` + `Equals()` + `GetHashCode()` (but not `==` until C# 7.3)

Inferred Tuple Names

(aka. Tuple Projection Initializers 😊)

- ▶ Tuple names are redundant when they can be inferred from the context
 - Similar to what the anonymous types of C# 3.0

```
struct Equipment
{
    public string Console { get; set; }
    public int Controllers { get; set; }
    public bool IsVREnabled { get; set; }
}
```

```
Equipment e = new Equipment { ... };
var tuple = (e.Console, e.Controllers);

Console.WriteLine( tuple.Console );
```

- ▶ Compiles in C# 7.1, but not in C# 7.0

Custom Tuple Deconstruction

- ▶ Can be easily deconstructed to individual parts

```
(int vowels, int cons) = FindVowels(input);
```

- ▶ Custom types can also be supplied with a *destructor* with out parameters

```
public class Employee  
{  
    ...  
    public void Deconstruct( out string firstName, out string lastName )  
    {  
        firstName = FirstName;  
        lastName = LastName;  
    }  
}
```

```
Employee elJefe = new Employee { ... };  
var (first, last) = elJefe;  
WriteLine(first);
```

- ▶ Works for two or more deconstruction parts
 - Deconstructors can be overloaded

Extension Deconstructors

- ▶ A powerful feature is that deconstructors can be extension methods

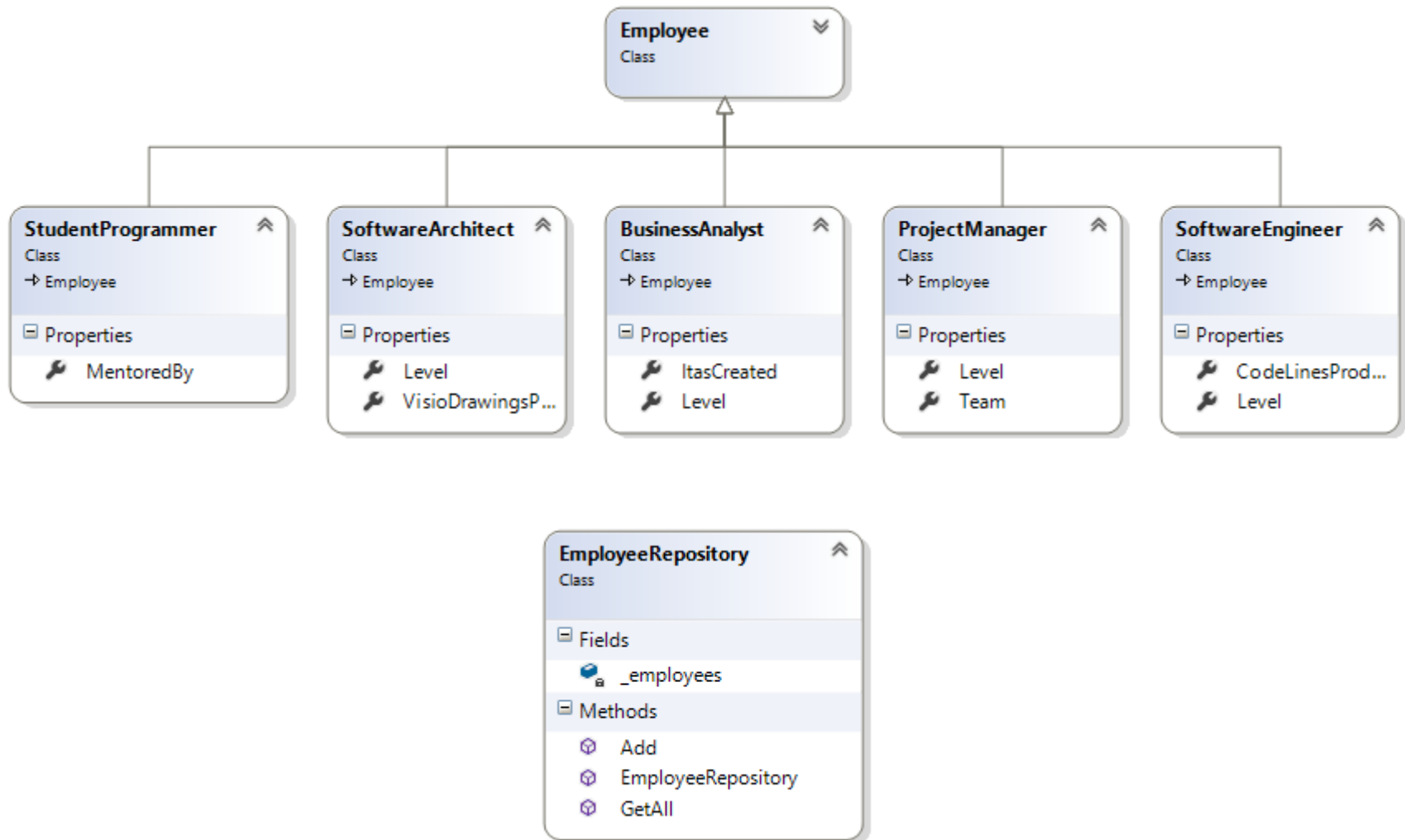
```
static class AlbumExtensions
{
    public static void Deconstruct(this Album album,
        out string summary, out int age)
    {
        summary = $"{album.AlbumName}\" by {album.Artist}";
        DateTime today = DateTime.Now;
        age = today.Year - album.ReleaseDate.Year -
            (album.ReleaseDate.DayOfYear < today.DayOfYear ? 0 : 1);
    }
}
```

- ▶ See Lab 01.2

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Example: Employee



Pattern Matching with **is**

- ▶ Three types of patterns for matching in C# 7
 - Constant patterns *c* e.g. **null**
 - Type patterns *T x* e.g. **int x**
 - Var patterns **var x**
- ▶ Matches and/or captures to identifiers to nearest surrounding scope
- ▶ More patterns are introduced in later C# versions

```
foreach (Employee e in all)
{
    if (e is SoftwareEngineer se)
    {
        WriteLine($"{se.FullName} has produced {se.CodeLinesProduced} " +
                    "lines of C#");
    }
}
```

- ▶ The **is** keyword is now compatible with patterns

Type Switch with Pattern Matching

- ▶ Can switch on any type
 - Case clauses can make use of patterns and new **when** conditions

```
Employee e = ...;
switch (e)
{
    case SoftwareArchitect sa:
        WriteLine($"{sa.FullName} plays with Visio");
        break;
    case SoftwareEngineer se when se.Level == SoftwareEngineerLevel.Lead:
        WriteLine($"{se.FullName} is a lead software engineer");
        break;
    case null:
    default:
        break;
}
```

- ▶ Cases are no longer disjoint – evaluated sequentially!

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Local Functions

- ▶ Methods within methods can now be defined

```
(int vowels, int cons) FindVowels( string s )  
{  
    ...  
    foreach (char letter in s)  
    {  
        bool IsVowel( char letter )  
        {  
            ...  
        }  
        ...  
    }  
    return tuple;  
}
```

- ▶ Has some advantages
 - Captures local variables
 - Avoids allocations

Ref Locals

- ▶ Can now create references in the style of C++
 - Similar to the **ref** modifier for parameters

```
int x = 42;  
ref int y = ref x;
```

```
x = 87;  
WriteLine(y);
```

Ref Locals Reassignment

- ▶ C# 7.0 added references in the style of C++
- ▶ C# 7.3 completes ref locals by allowing them to be reassigned

```
int x = 42;  
int y = 87;  
ref int z = ref x; // Declaration and Initialization of z;  
  
x = 112;  
WriteLine($"z = {z}");  
  
z = ref y; // Reassignment of z;  
WriteLine($"z = {z}");
```


Ref Conditionals

- ▶ C# 7.2 allows the well-known selection operator `?:` for refs

```
int x = 42;  
int y = 87;  
bool b = ...;  
  
ref int z = ref (b ? ref x : ref y);  
  
z = 112;  
  
Console.WriteLine( $"x={x}, y={y}, z={z}");
```

Ref Returns

- ▶ Methods can now also return references

```
ref int FindMax( int[] numbers )
{
    int indexOfMax = 0;
    for (int i = 1; i < numbers.Length; i++)
    {
        if (numbers[i] > numbers[indexOfMax])
        {
            indexOfMax = i;
        }
    };

    return ref numbers[indexOfMax];
}
```

- ▶ Can only return references to heap-based values – not locals

Ref Readonly

- ▶ Ref Returns can be enforced read-only by the compiler

```
ref readonly int FindMax( int[] numbers )  
{  
    int indexOfMax = 0;  
    ...  
    return ref numbers[indexOfMax];  
}
```

```
ref readonly int max = ref FindMax(numbers);  
WriteLine($"{nameof(max)} is now {max}");
```

```
max = 1000; // Not allowed!
```

- ▶ Must manually create a copy to make it modifiable later

```
int maxCopy = FindMax(numbers); // Copy  
maxCopy = 999999;
```

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More Expression-bodied Members

- ▶ Earlier only getters and methods could be expression-bodied

```
public class Person
{
    ...
    public Person( string name ) => Names.Add(_id, name);

    ~Person() => Names.Remove(_id);

    public string Name
    {
        get => Names[_id];
        set => Names[_id] = value;
    }
}
```

- ▶ New in C# 7.0
 - Constructors
 - Destructors
 - Setters

Throw Expressions

- ▶ In C# 6 one could not easily just throw an exception in an expression-bodied member
- ▶ C# 7 allows **throw** expressions as subexpressions
 - Also outside of expression-bodied members..!

```
public class EmployeeRepository : IEmployeeRepository
{
    private readonly IList<Employee> _employees;
    ...
    public void Add( Employee employee ) =>
        _employees.Add(employee ??
            throw new ArgumentNullException(nameof(employee)));
}
```


- ▶ Note that a **throw** expression does not have an expression type as such...

Declaration Expressions: **out var**

- ▶ Introduces local variable in nearest surrounding scope

```
string s = ReadLine();  
int result;  
if (int.TryParse(s, out result))  
{  
    WriteLine(result);  
}
```

- ▶ Visual Studio has a handy refactoring for this



```
string s = ReadLine();  
if (int.TryParse(s, out int result))  
{  
    WriteLine(result);  
}
```

Discards

- ▶ Temporary, dummy variables which are intentionally unused in application code

```
Employee elJefe = new Employee { ... };  
var (first, _) = elJefe;  
WriteLine(first);
```

```
if (int.TryParse(s, out _))  
{  
    // s is a legal int  
}
```

- ▶ Supported scenarios
 - Tuples and object deconstruction
 - Pattern matching
 - Calls to methods with **out** parameters
 - A standalone `_` (when no `_` is in scope)

Binary Literals and Digit Separators

```
enum FileAttributes
{
    ReadOnly =          0b00_00_00_00_00_00_01, // 0x0001
    Hidden =            0b00_00_00_00_00_00_10, // 0x0002
    System =            0b00_00_00_00_00_01_00, // 0x0004
    Directory =         0b00_00_00_00_00_10_00, // 0x0008
    Archive =           0b00_00_00_00_01_00_00, // 0x0010
    Device =            0b00_00_00_00_10_00_00, // 0x0020
    Normal =            0b00_00_00_01_00_00_00, // 0x0040
    Temporary =         0b00_00_00_10_00_00_00, // 0x0080
    SparseFile =        0b00_00_01_00_00_00_00, // 0x0100
    ReparsePoint =      0b00_00_10_00_00_00_00, // 0x0200
    Compressed =        0b00_01_00_00_00_00_00, // 0x0400
    Offline =           0b00_10_00_00_00_00_00, // 0x0800
    NotContentIndexed = 0b01_00_00_00_00_00_00, // 0x1000
    Encrypted =         0b10_00_00_00_00_00_00 // 0x2000
}
```

Leading Underscores in Numeric Literals

- ▶ Starting from C# 7.2 the numeric literals of C# 7.0 are allowed to start with an underscore

```
int i = 0b00_00_00_00_00_00_01; // Allowed in C# 7.0
int j = 0b_00_00_00_00_00_00_01; // Allowed in C# 7.2
int k = 0x_ffffff;                // Allowed in C# 7.2
int m = 8_7;                      // Allowed in C# 7.0
int n = _8_7;                     // Not allowed
```

- ▶ Note:
 - Only allowed for hexadecimal and binary literals
 - Not decimals...!

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Evolution of C# 7.1



Async Main()

```
static async Task DoStuffAsync()
```

```
{
```

```
    ... await ...
```

```
    ... await ...
```

```
    ... await ...
```

```
}
```

```
static void Main(string[] args)
```

```
{
```

```
    DoStuffAsync().GetAwaiter().GetResult();
```

```
}
```

```
static async Task<int> Main( string[] args )
```

```
{
```

```
    ... await ...
```

```
}
```

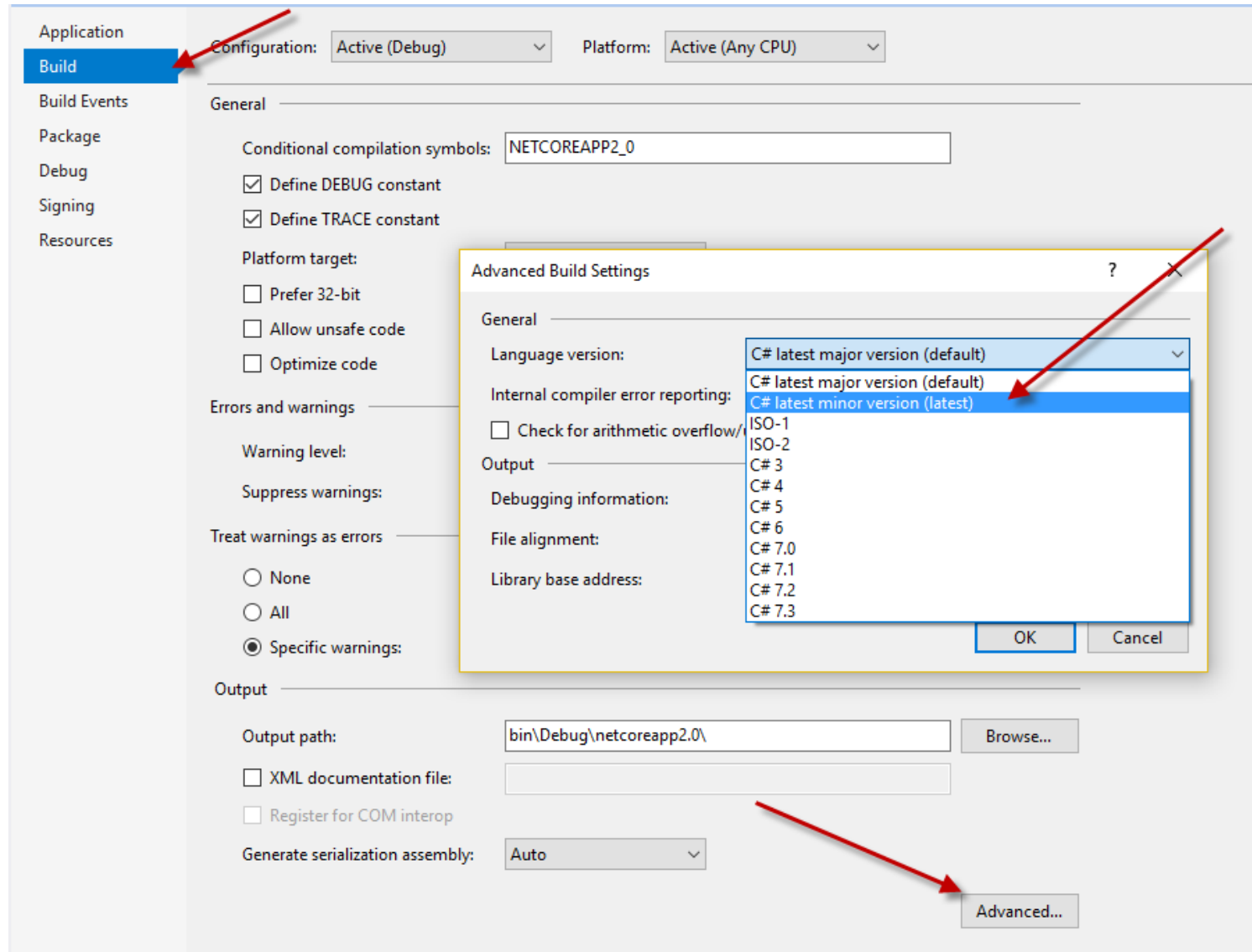
```
int $GeneratedMain( string[] args )
```

```
{
```

```
    return Main(args).GetAwaiter().GetResult();
```

```
}
```

Enabling C# 7.x in Visual Studio 2017



Visual Studio 2019+2022

Default C# Versions

Target framework	version	C# language version default
.NET	6.x	C# 10.0
.NET	5.x	C# 9.0
.NET Core	3.x	C# 8.0
.NET Core	2.x	C# 7.3
.NET Standard	2.1	C# 8.0
.NET Standard	2.0	C# 7.3
.NET Standard	1.x	C# 7.3
.NET Framework	all	C# 7.3

- ▶ Visual Studio 2017 introduced **LangVersion** in project file
- ▶ Visual Studio 2019 + 2022 attempts to use defaults

Pattern Matching Open Types

- ▶ Patterns now play well with (sub-)type constraints for generic types


```
static void Promote<T>( T employee )
{
    switch (employee)
    {
        case SoftwareArchitect sa:
            sa.Level = SoftwareArchitectLevel.Lead;
            break;
        case SoftwareEngineer se:
            se.Level = SoftwareEngineerLevel.Chief;
            break;
    }
}
```

- ▶ Compiles in C# 7.1, but not in C# 7.0

Default Literal

- ▶ C# 7.1 now allows to omit the type in the default operator
 - When the type can be deferred from the context

```
bool flag = false;  
int i = flag ? 87 : default(int);  
WriteLine(i);
```



```
bool flag = false;  
int i = flag ? 87 : default;  
WriteLine(i);
```

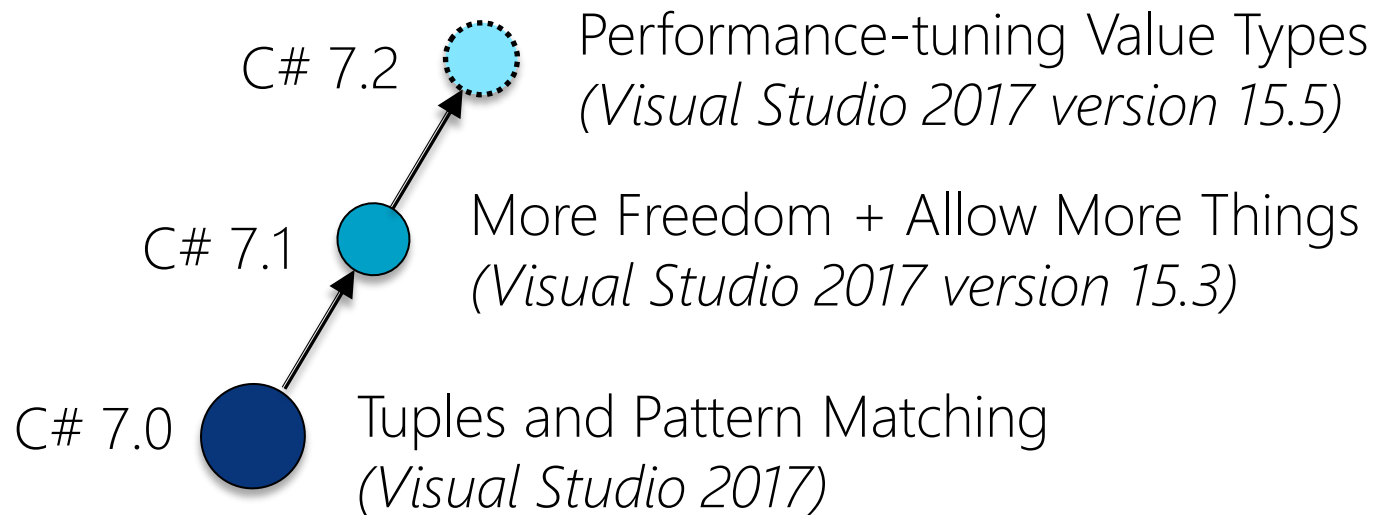
- ▶ Compiles in C# 7.1, but not in C# 7.0
- ▶ Has a number of nice and simple uses such as

```
void DoStuff( int x, int y = default, bool z = default )  
{  
    WriteLine($"x={x}\ty={y}\tz={z}");  
}
```


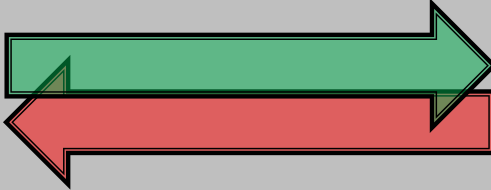


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Evolution of C# 7.2



in Parameter Modifier

Modifier	Effect	Description
		Copies argument to formal parameter
ref		Formal parameters are synonymous with actual parameters. Call site must also specify ref
out		Parameter cannot be read. Parameter must be assigned. Call site must also specify out
in		Parameter is "copied". Parameter cannot be modified! Call site can optionally specify in . ~ "readonly ref"

in Parameter Modifier

- ▶ It can be passed as a reference by the runtime system for performance reasons

```
double CalculateDistance( in Point3D first, in Point3D second = default )
{
    double xDiff = first.X - second.X;
    double yDiff = first.Y - second.Y;
    double zDiff = first.Z - second.Z;

    return Sqrt(xDiff * xDiff + yDiff * yDiff + zDiff * zDiff);
}
```

- ▶ The call site does not need to specify **in**
- ▶ Can call with constant literal -> Compiler will create variable

```
Point3D p1 = new Point3D { X = -1, Y = 0, Z = -1 };
Point3D p2 = new Point3D { X = 1, Y = 2, Z = 3 };
double d = CalculateDistance(p1, p2);
```

Readonly Structs

- ▶ Define immutable structs for performance reasons

```
readonly struct Point3D
{
    public double X { get; }
    public double Y { get; }
    public double Z { get; }

    public Point3D( double x, double y, double z ) { ... }

    public override string ToString() => $"({X},{Y},{Z})";
}
```

- ▶ Can always be passed as **in**
- ▶ Can always be **readonly ref** returned
- ▶ Compiler generates more optimized code for these values

Ref Structs

- ▶ Structs can be enforced as “always stack allocated” using **ref struct**

```
ref struct Point3D
{
    public double X { get; }
    public double Y { get; }
    public double Z { get; }
    ...
}
```

- ▶ These values can never be allocated on the heap
 - Cannot be boxed
 - Cannot be declared members of a class or (non-ref) struct
 - Cannot be local variables in async methods
 - Cannot be declared local variables in iterators
 - Cannot be captured in lambda expressions or local functions

Span<T> and ReadOnlySpan<T>

- ▶ Ref-like types to avoid allocations on the heap
 - Don't have own memory but points to someone else's
 - Essentially: "ref for sequence of variables"

```
int[] array = new int[10];  
...  
Span<int> span = array.AsSpan();  
Span<int> slice = span.Slice(2, 5);  
foreach (int i in slice)  
{  
    Console.WriteLine( i );  
}
```

```
string s = "Hello, World";  
ReadOnlySpan<char> span = s.AsSpan();  
ReadOnlySpan<char> slice =  
    span.Slice(7, 5);  
foreach (char c in slice)  
{  
    Console.Write(c);  
}
```

- ▶ Note:
 - Located in System.Memory prerelease nuget package

Non-trailing Named Arguments

- ▶ As of C# 7.2 named arguments can now be followed by positional arguments...
 - ... but only if named argument is used in the **correct** position

```
void M( int x, int y = 87, bool z = default )  
{  
    Console.WriteLine($"x = {x}, y = {y}, z = {z}");  
}
```

```
M(1, 2, true);           // Allowed in C# 4.0  
M(x: 1, 2, z: true);    // Allowed in C# 7.2 (but not C# 7.1)  
M(z: true, 1);          // Not allowed!
```

private protected Access Modifier

▶ private protected

- Is visible to containing types
- Is visible to derived classes in the same assembly

```
public class ClassInOtherAssembly
{
    private protected int X { get; set; }

    public void Print() => Console.WriteLine(X);
}
```

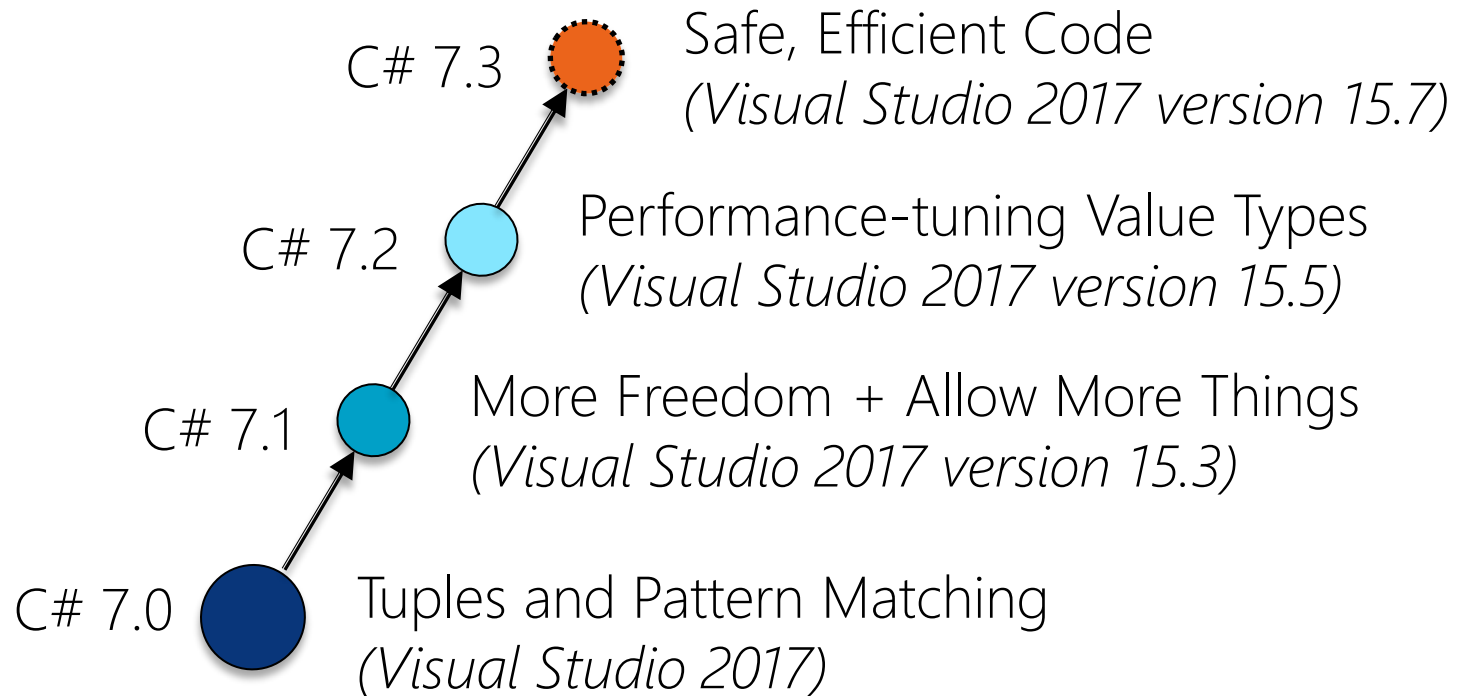
▶ protected internal

- Is visible to types in same assembly
- Is visible to derived classes (in same or other assemblies)

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Evolution of C# 7.3



Expression Variables in Initializers

- ▶ More flexible initialization was introduced in C# 7.0
- ▶ C# 7.3 extends out var and pattern variables to initializers

```
class Base
{
    public int Coordinate { get; } =
        int.TryParse("hello", out int x) ? x : default;

    public Base( int coordinate = default ) => Coordinate = coordinate;
}
```

```
class Derived : Base
{
    public Derived( object o ) : base(o is Point p ? p.X : default)
    {
    }
}
```

Attributes on Backing Fields

- ▶ C# 7.3 allows attributes targeting the backing fields for auto-properties

```
[Serializable]
class ShoppingCartItem
{
    public int ProductId { get; }
    public decimal Price { get; }
    public int Quantity { get; }
    [field:NonSerialized]
    public decimal Total { get; }

    public ShoppingCartItem( int productID, decimal price, int quantity )
    {
        ProductId = productID;
        Price = price;
        Quantity = quantity;
        Total = price * quantity;
    }
}
```

More Generic Constraints

Generic Constraint	Description
<code>where T : struct</code>	T must ultimately derive from System.ValueType
<code>where T : class</code>	T must be a reference type
<code>where T : new()</code>	T must have a default constructor
<code>where T : BaseClass</code>	T must derive from the class <i>BaseClass</i> T can now be System.Enum T can now be System.Delegate
<code>where T : Interface</code>	T must implement the interface <i>Interface</i>
<code>where T : unmanaged</code>	T must be "unmanaged", i.e. can take unmanaged pointer to T

Enum Constraints

- ▶ Finally(!) we can now do proper enum constraints on generic types

```
public static T GetRandomMember<T>() where T : struct, Enum
{
    Random random = new Random();
    T[] ts = Enum.GetValues(typeof(T))
        .OfType<T>()
        .ToArray()
        ;

    return ts[random.Next(ts.Length)];
}
```

- ▶ *See Lab 01.7*

Misc. Unmanaged Interop

- ▶ Now **stackalloc** expressions can have initializers

```
Span<int> span = stackalloc int[] { 11, 22, 33 };
```

- ▶ Indexing movable fixed buffers (without pinning)

```
unsafe struct S  
{  
    public fixed int FixedField[10];  
}
```

```
static S s;  
...  
// No fixed required  
int i = s.FixedField[5];
```

- ▶ Custom fixed statement

```
byte[] byteArray = new byte[10];  
fixed (byte* ptr = byteArray)  
{  
    // byteArray is protected from being moved/collected by the GC  
    // for the duration of this block  
}
```

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WINCUBATE

Jesper Gulmann Henriksen

PhD, MCT, MCSD, MCPD

Phone : +45 22 12 36 31

Email : jgh@wincubate.net

WWW : <http://www.wincubate.net>

Ringgårdsvej 4A

8270 Højbjerg

Denmark