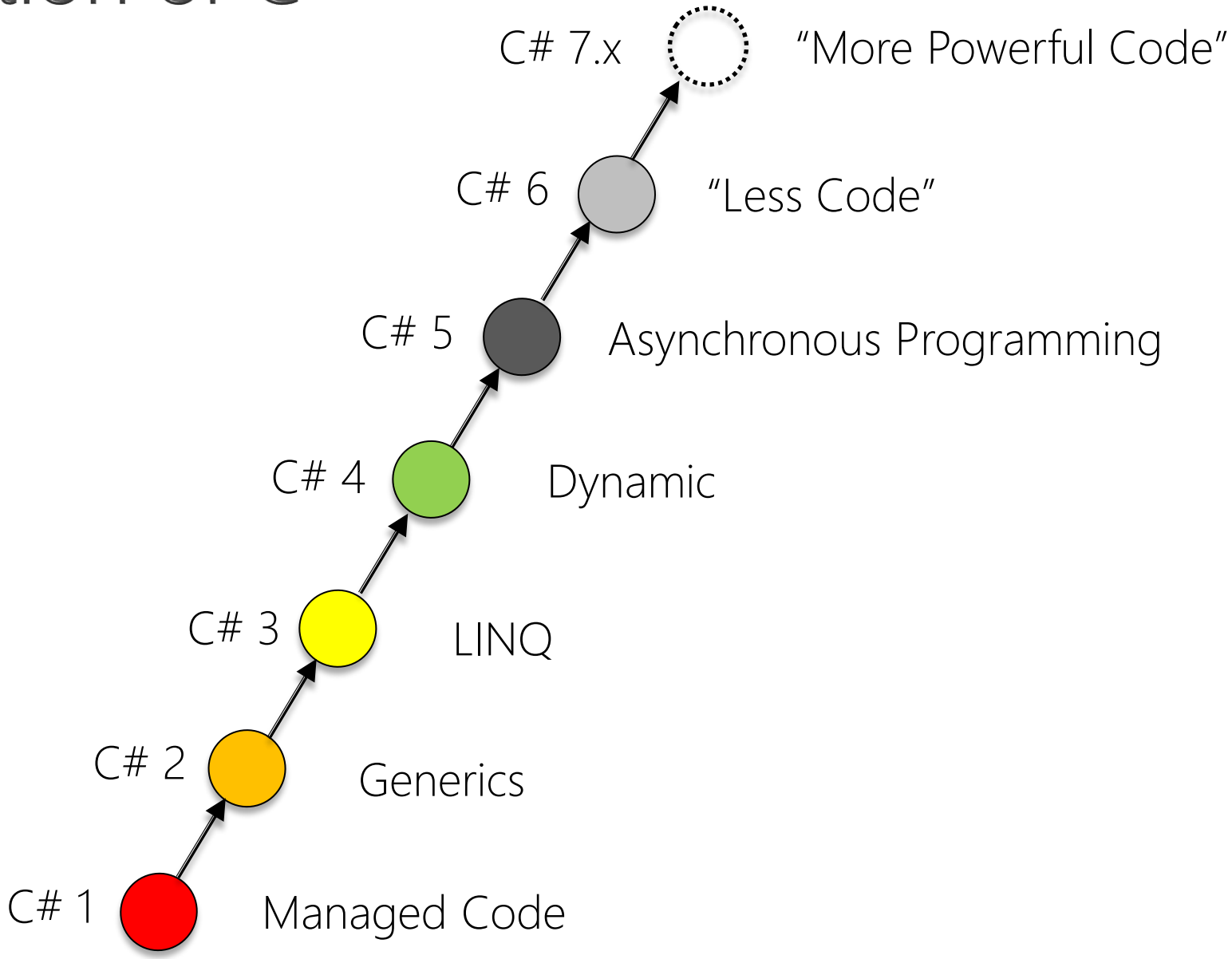
Module 01:

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

Evolution of C#



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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 *deconstructor* with out parameters

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

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

- 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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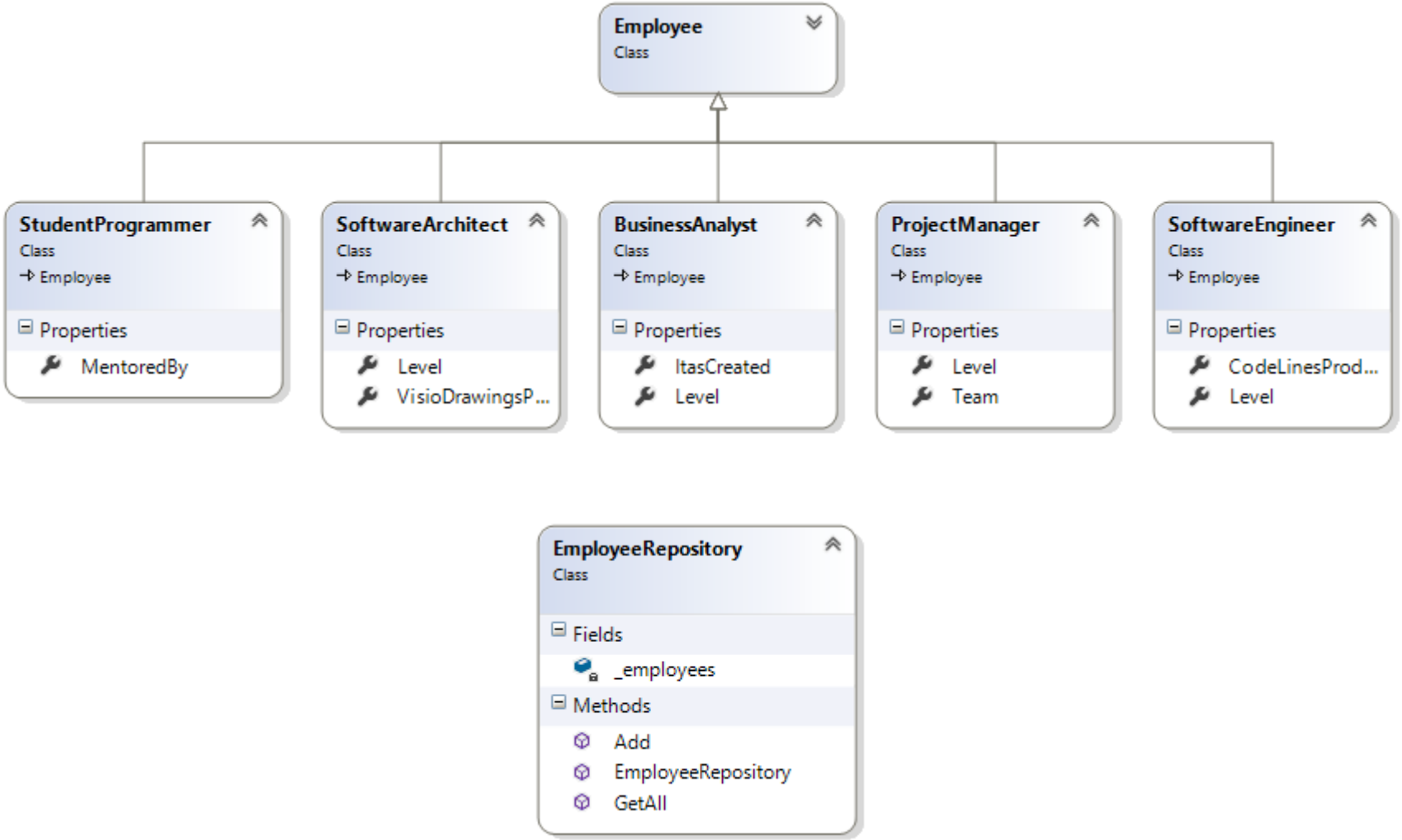
Example: Employee



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 numerics 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_ffff;                 // 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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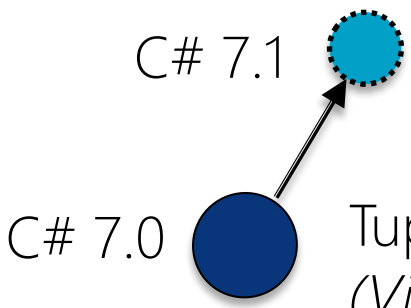
Evolution of C# 7.1

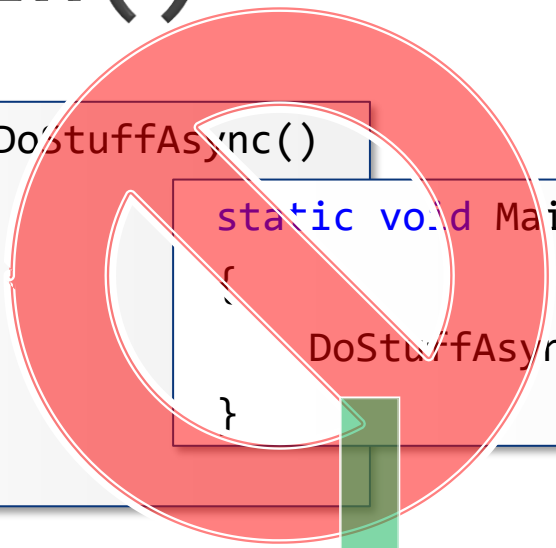


More Freedom + Allow More Things
(Visual Studio 2017 version 15.3)

Tuples and Pattern Matching
(Visual Studio 2017)

Async Main()

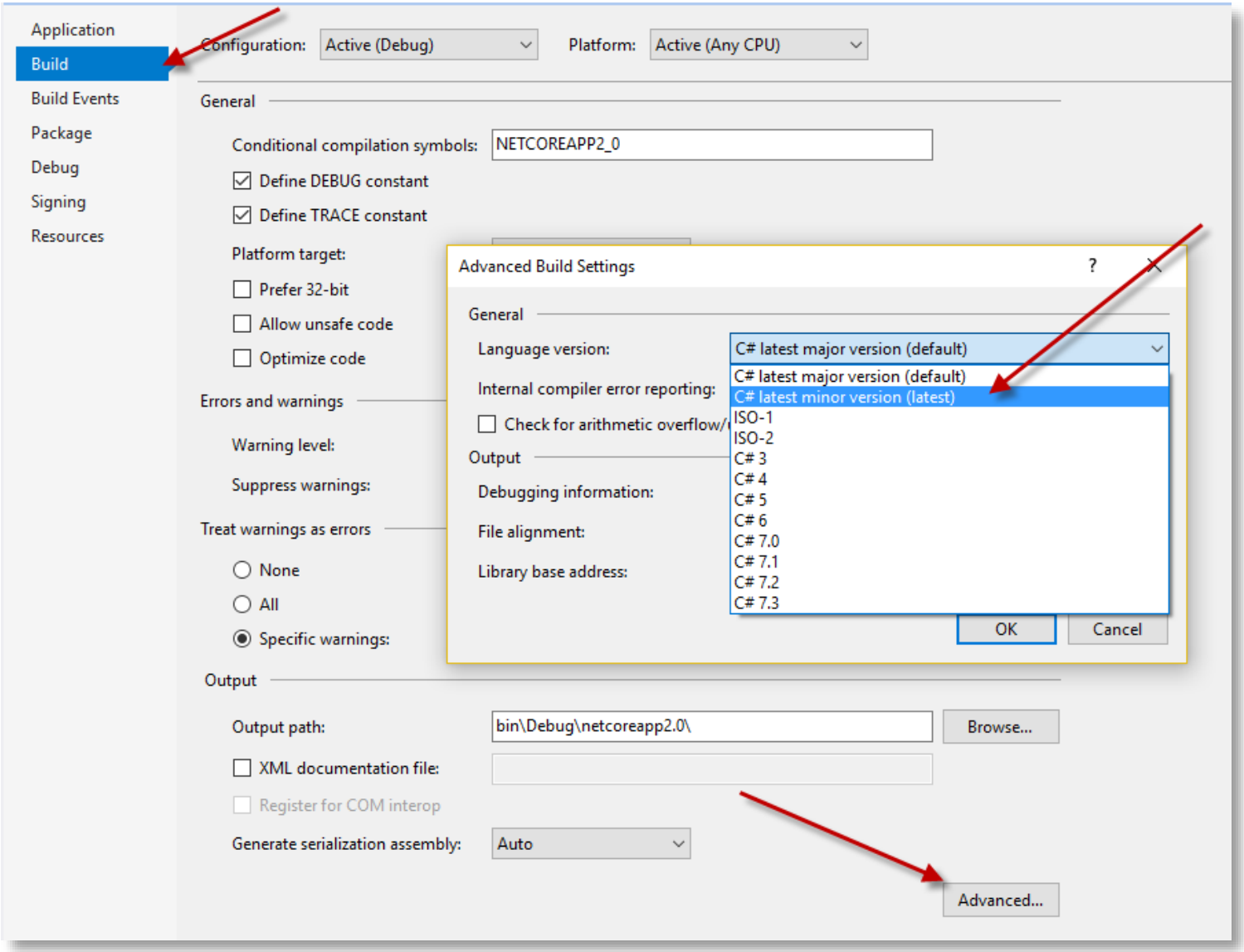
```
static async Task DoStuffAsync()
{
    ... await ...
    ... await ...
    ... await ...
}
```



```
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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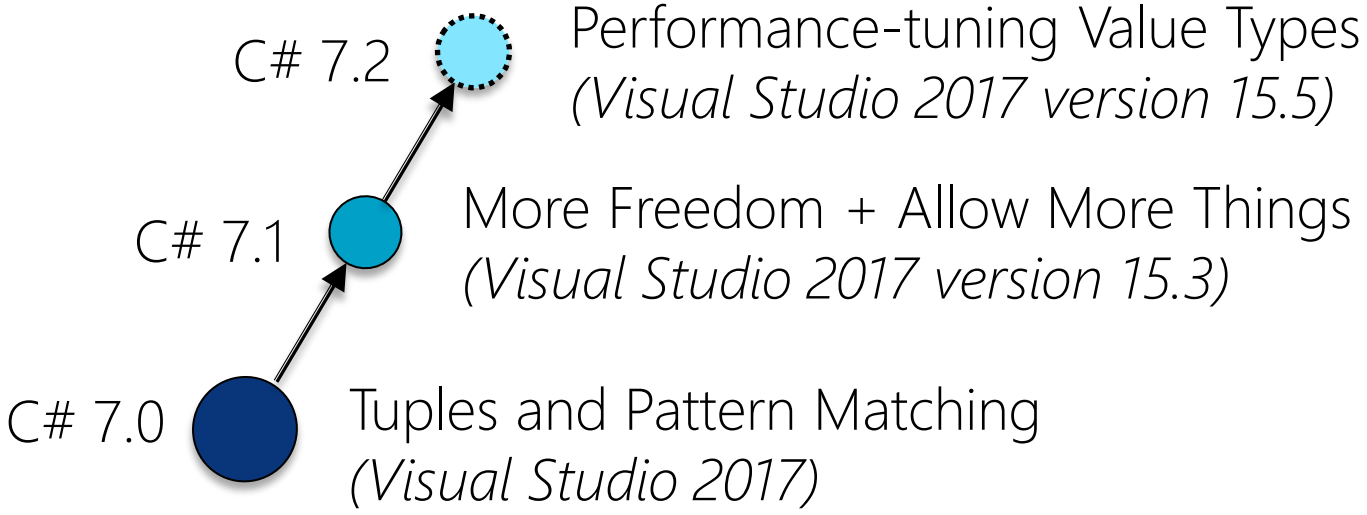
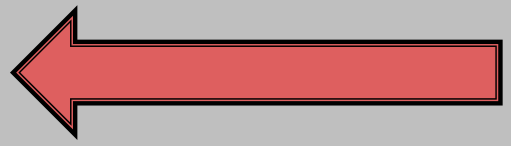
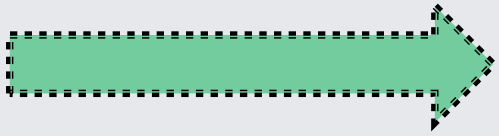
Evolution of C# 7.2



`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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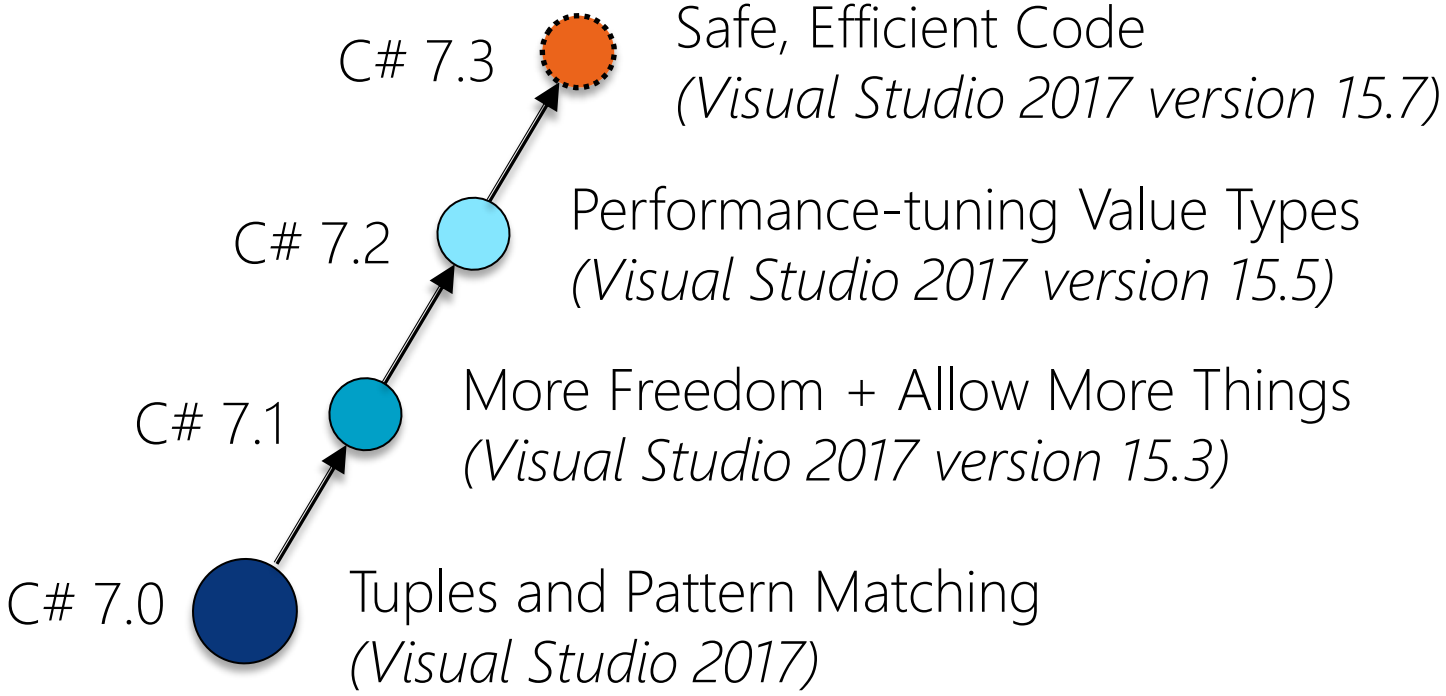

Expression Variables in Initializers

- 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
`where T : struct`	T must ultimately derive from `System.ValueType`
`where T : class`	T must be a reference type
`where T : new()`	T must have a default constructor
`where T :` *BaseClass*	T must derive from the class *BaseClass* T can now be `System.Enum` T can now be `System.Delegate`
`where T :` *Interface*	T must implement the interface *Interface*
`where T : unmanaged`	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