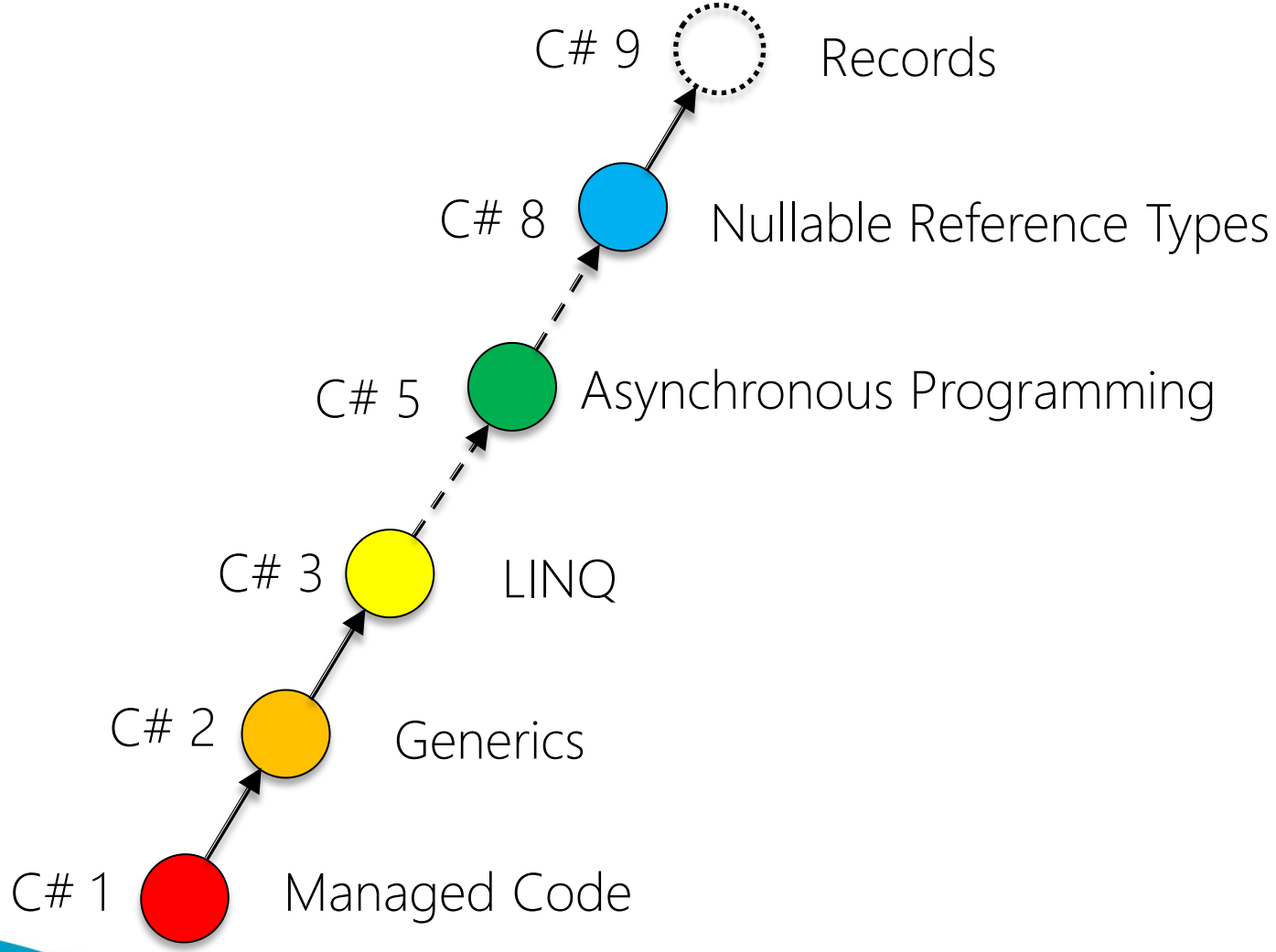
Module 03:

"An Introduction to C# 9"

Major Evolutions of C#



Agenda

- Introduction
- **Object-Oriented Improvements**
- Statement Improvements
- Expression Improvements
- Method Improvements
- Performance, Interop, and Code Generation
- Summary

Init-only Setters

- Restricted setter only allowing initialization:

```
public sealed class Album
{
    public string Artist { get; init; }
    public string AlbumName { get; init; }
    public DateTime ReleaseDate { get; init; }

    ...
}
```

- Can have usual visibility on init-only setter
- Can not have both **`init`** and **`set`**...!

Records

- Records are simpler, immutable classes

```
record Person(string FirstName, string LastName);
```

- Defines init-only properties with “Primary Constructors”

- Can have additional properties + methods, of course

```
record Album(string Artist, string AlbumName, DateTime ReleaseDate)
{
    public int Age
    {
        get { ... }
    }
}
```

Built-in Features of Records

- Overrides
  - `ToString()`
  - `Equals()` (Implements `IEquatable<T>`)
  - `GetHashCode()`
  - `==` and `!=`
- What about `ReferenceEquals`?
- Supplies built-in deconstructors

Mutation-free Copying

- Additional keyword: Create copies using `with`

```
Album album = new Album("Prince",
                        "Purple Rain",
                        new DateTime(1984, 11, 02));

Album renamed = album with
{
    Artist = "The Artist Formerly Known as..."
};
```

- Does not mutate source record
  - Copies and replaces

Records and Inheritance

- Almost all OO aspects are identical to classes
  - Visibility, parameters, etc.
  - But Records and Classes cannot mix inheritance!

- Can override and change built-in method overrides, if needed

A Few Words of Warnings

- Could we “break” immutability manually?
- What if we override `ToString()` on `Record`?
- What happens if we add “`Albums`” as a property?

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Top-level Statements

- A fundamental rule of C# has now been relaxed:

```
using System;
namespace Wincubate.CS9.B
{
    class Program
    {
        static void Main(string[] args)
        {
            Console.WriteLine("Hello World!");
        }
    }
}
```

- But what about the arguments then?

Extension Enumerables

- It is possible to create an "extension implementation" of `IEnumerable<T>` for a third-party type
  - `foreach` now respects extension `GetEnumerator<T>` methods

```
static class SequenceExtensions
{
    public static IEnumerator<T> GetEnumerator<T>( this Sequence<T> t )
    {
        SequenceElement<T>? current = t.Head;
        while (current != null)
        {
            yield return current.Data;
            current = current.Next;
        }
    }
}
```

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Pattern-matching Enhancements

- C# 7 and 8 introduced a total of 6 patterns

- C# 9 introduces 6 additional patterns or enhancements:

• Type patterns	*Type*	e.g. **`int`**
• Negation patterns	not *P1*	e.g. **`not null`**
• Parenthesized patterns	(*P*)	e.g. **`(string)`**
• Conjunctive patterns	*P1 and P2*	e.g. **`A and (not B)`**
• Disjunctive patterns	*P1 or P2*	e.g. **`int or string`**
• Relational patterns	*P1 < P2*	e.g. **`< 87`**
	P1 <= P2	e.g. **`<= 87`**
	P1 > P2	e.g. **`> 87`**
	P1 >= P2	e.g. **`>= 87`**

Type Patterns

- This is more or less only a compiler-theoretic enhancement
  - But now it "mixes better" with the new or compound patterns

```
object o1 = 87;
object o2 = "Yeah!";

var t = (o1, o2);

if (t is (int, string))
{
    Console.WriteLine("o1 is an int and o2 is a string");
}
```

Negation Patterns

- At last(!) we are allowed negative pattern assertions

```
public void DoStuff(object o)
{
    if( o is not null )
    {
        Console.WriteLine(o);
    }
}
```

Parenthesized Patterns

- This is simply a means to disambiguate parsing
  - Carries not semantic meaning in itself

```
public string WhatIsIt(object o) =>
    o switch
    {
        (((string))) => "string",
        (((int))) => "int",
        _ => "Something else :-)",
     };
```

- But has tremendous significance for the other patterns following shortly…

Conjunctive Patterns

- Conjunctive patterns specify an **and** between patterns

```
string evalution = employee switch
{
    (not ProjectManager) and (not StudentProgrammer) =>
        "Codes a little",
    _ => "Probably codes a bit more..."
};

Console.WriteLine($"{employee.FullName}: {evalution}");
```

Disjunctive Patterns

- Disjunctive patterns specify an **or** between patterns

```
IEnumerable<object> elements = new List<object>
{
    42, "Yay", 87.0, "Nay", 12.7m
};

foreach (var o in elements)
{
    Console.WriteLine(o switch {
        int or double or decimal => $"{o} is a number",
        _ => "Not a number..."
    });
}
```

Relational Patterns

- The relational patterns are all the "usual" comparisons
  - `<` , `<=` , `>` , `>=`

```
int temperature = int.Parse(Console.ReadLine());

string forecast = temperature switch
{
    <= 0 => "Freezing...",
    < 12 => "Autumn-like",
    <= 19 => "Spring-ish",
    <= 40 => "Summer!",
    _ => "Death Valley?"
};
```

- Note that there is no `=>`

Target-typed New

- Target-typed new expressions are essentially the "counterpart" of `var`

```
Dictionary<string, List<int>> field = new()
{
   { "item1", new() { 1, 2, 3 } }
};
```

- There are a number of disallowed scenarios:
  - Interfaces
  - Enums
  - Dynamic types
  - Tuples
  - …

Target-Typed Conditionals

- New implicit conditional expression conversion:

```
bool b = true;
int i = 87;

Console.WriteLine($"Result: {( b ? i : null)}");
```

- There are some slightly strange implications, but works well in practice ☺

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Covariant Return Types

- Return types for methods are now relaxed to covariance

```
public class ConfigProvider
{
   public virtual Config GetConfig() { ... }
}

public class AppleConfigProvider : ConfigProvider
{
    public override AppleConfig GetConfig() { ... }
}
```

- Must exist an implicit conversion

- What about interface, strings, int, doubles, … ?

Lambda Discard Parameters

- Previous versions of C# introduced discards in various guises – C# 9 extends to lambda expressions

```
using System;

Func<int, int, int?> add = (x, y) => x + y;
Func<int, int, int?> nullFunction = (_, _) => 0;

Console.WriteLine(add(42, 87));
Console.WriteLine(nullFunction(42, 87));
```

- Beware of edge-cases for single params or existing vars

Static Anonymous Functions

- C# 7.0 introduced local function
- C# 8.0 introduced static local functions
- C# 9.0 introduces status anonymous (and lambda) functions

```
foreach (char letter in s)
{
   static bool IsVowel(char letter) => char.ToLower(letter) switch
   {
      'a' or 'e' or 'i' or 'o' or 'u' or 'y' or 'æ' or 'ø' or ‘å’
         => true,
       _ => false,
    }
    ...
};
```

- No capture of locals, members and use of **`this`**, **`base`**.

Attributes on Local Methods

- Attributes can now be placed on local functions and lambdas
  - Levelling the playing field for methods variations

```
void Main(string[] args)
{
    [Conditional("DEBUG")]
    static void PrintInfo(string s) =>
    {
        Console.WriteLine($"Debug: {s}");
    }

    PrintInfo("Start");
}
```

- Method must be static!
- Note: Local methods can now also be marked `extern`

Revisiting Partial Methods

```
partial class Customer
{
    private string _name;
    public string Name
    {
        get { return _name; }
        set
        {
            OnNameChanging(value);
            _name = value;
            OnNameChanged();
        }
    }
    partial void OnNameChanging(string newName);
    partial void OnNameChanged();
}
```

New Features for Partial Methods

- Traditionally, partial methods suffered some restrictions:
  - ~~Cannot define access modifiers (implicitly private)~~
  - ~~Must have `void` return type~~
  - ~~Parameters cannot have the `out` modifier~~

- These restrictions are removed if
  - Can be annotated with explicit accessibility modifier (if consistent)
  - When explicit modifier, it must have a matching implementation

```
partial class Customer
{
    ...
    private partial bool OnNameChanging(string newName);
    public partial void OnNameChanged(out string oldName);
}
```

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Native-Sized Integers

- For interop scenarios and low-level libraries:
  - `nint` ~ `System.IntPtr`
  - `nuint` ~ `System.UIntPtr`

```
unsafe
{
    nint y = 87;
    Console.WriteLine(y);
    Console.WriteLine(sizeof(nint));
}
```

- Extended with a lot of conversions and operations

Function Pointers

- Pretty much only for emitting highly optimized unsafe code

```
unsafe class Example
{
    public void Compute(Action<int> a, delegate*<int, void> f)
    {
        a(42);
        f(42);
    }
}
```

- Not for “ordinary” people… ☺

Suppress Localsinit

- Optimization technique for really advanced low-level library authors:

```
[SkipLocalsInit]
unsafe class Entity
{
    public void DoStuff(out int a)
    {
        // a will contain "non-zero'ed" memory if read here
        a = 87;
    }
}
```

- Avoids the penalty of zero-whitewashing memory

Module Initializers

- A module initializer runs whenever the module is loaded!
  - The method must be static.
  - The method must be parameterless.
  - The method must return `void`.

```
class C
{
    [ModuleInitializer]
    internal static void InitializeLogFile()
    {
        File.CreateText(_fileName);
    }
}
```

- There can be several module initializers

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