Introduction to .NET and C# Language

What is .NET Framework?

- **.NET Framework** is a **Windows-only software development platform** developed by Microsoft.
- Released in **2002**, it provides a large library of pre-built code, known as the **Framework Class Library (FCL)**, and supports multiple programming languages like **C#, VB.NET, F#**.
- It runs on the **Common Language Runtime (CLR)**, which manages memory, security, and exception handling.
- Mainly used for:
    - Windows desktop applications (WinForms, WPF)
    - ASP.NET Web Forms / MVC applications
    - Enterprise-level software

Limitations:

- Only runs on Windows OS
- Not ideal for modern cross-platform development

What is .NET Core?

- **.NET Core** is an **open-source, cross-platform** version of .NET launched by Microsoft in **2016**.
- Supports **Windows, Linux, and macOS**.
- Modern and optimized for:
    - Cloud-based apps
    - Web apps (via ASP.NET Core)
    - Microservices
    - High-performance APIs

Now: .NET Core evolved into **.NET 5+** (known simply as **.NET** now) starting from .NET 5, merging the best of .NET Framework and .NET Core.

Key Differences between .NET Framework and .NET Core:

Feature	.NET Framework	.NET Core / .NET 5+
Platform	Windows only	Cross-platform (Windows, Linux, macOS)
Open-source	No	Yes
Performance	Good	Excellent (optimized for performance)
Application Type	Windows apps, web apps	Modern web, cloud, microservices
Deployment	System-wide installation	Can be self-contained with app
Latest Development	Only security fixes	Actively developed and updated

What is Visual Studio?

- **Visual Studio** is **Microsoft's Integrated Development Environment (IDE)**.
- It's a powerful tool for writing, debugging, testing, and deploying applications.
- Supports multiple languages: **C#, VB.NET, F#, C++, Python, JavaScript**, etc.

Role of Visual Studio in Application Development:

1. **Code Editor:** Write code with syntax highlighting, IntelliSense (auto-completion), and refactoring tools.
2. **Designer Tools:** Drag-and-drop designers for UI building (WinForms, WPF, Web apps).
3. **Debugger:** Step through code, inspect variables, and troubleshoot bugs easily.
4. **Project Templates:** Start projects quickly (Web API, Console app, WPF, Blazor, etc.).
5. **Build & Deployment:** Compiles code, manages dependencies (NuGet), and helps deploy to servers or the cloud.
6. **Version Control:** Integrated Git support for version control and collaboration.
7. **Testing:** Tools for unit testing, integration testing, and performance testing.

Summary in Simple Terms:

Term	Meaning/Role
.NET Framework	Old, Windows-only development platform
.NET Core / .NET	Modern, cross-platform development framework
Visual Studio	All-in-one tool (IDE) to build, debug, test, and deploy applications

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Great question! Let's break down the **C# execution process** under **.NET Framework** and **.NET Core (or .NET 5/6/7+)** — the process is similar but with some differences based on the runtime environment.

C# Program Execution Process (Execution Flow in .NET Framework and .NET Core):

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1 Write Code (C# Source Code)

- You write the `.cs` file(s) (e.g., `Program.cs`) in Visual Studio or another IDE.

```
using System;
class Program
{
    static void Main()
    {
        Console.WriteLine("Hello, World!");
    }
}
```

2 Compilation (Source Code → Intermediate Language (IL))

- The **C# compiler (csc.exe)** converts `.cs` files into **Intermediate Language (IL)** code.
- Output is an **assembly (.exe or .dll)**.

IL is platform-independent.

Example command (simplified):

```
csc Program.cs → Program.exe
```

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3 Metadata and Assembly Creation

- Along with IL, the compiler generates **metadata** (information about classes, methods, types).
- Both IL and metadata are stored in the **.exe** or **.dll** file.

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4 Execution by CLR / CoreCLR

Depending on the framework, the execution environment varies:

Framework	Runtime	Role
.NET Framework	**CLR (Common Language Runtime)**	Manages memory, security, exception handling
.NET Core / .NET 5+	**CoreCLR** or **.NET Runtime**	Lighter, faster, cross-platform runtime engine

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5 Just-In-Time (JIT) Compilation

- At runtime, the **CLR/CoreCLR** reads the IL and compiles it into **machine code** specific to the operating system and hardware using **JIT (Just-In-Time) Compiler**.

Example:

```
IL → JIT → Native Machine Code → CPU Executes
```

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6 Execution

- The CPU runs the native machine code.
- The **runtime (CLR/CoreCLR)** handles:
  - **Memory Management (Garbage Collection)**
  - **Security**

- **Exception Handling**
- **Thread Management**
- **Interop with unmanaged code (C/C++)**

Diagram Overview

```
C# Code (.cs)
    ↓ [Compile - csc.exe]
Intermediate Language (IL) + Metadata (.exe / .dll)
    ↓ [Load - CLR/CoreCLR]
Just-In-Time (JIT) Compilation
    ↓
Native Machine Code
    ↓
Execution on CPU
```

Differences Between .NET Framework and .NET Core Execution:

Step	.NET Framework	.NET Core / .NET 5+
Runtime	CLR (Windows-only)	CoreCLR / .NET Runtime (Cross-platform)
Deployment	Installed on Windows machine	Can be installed globally or bundled (self-contained)
Performance	Moderate	Faster and optimized JIT (RyuJIT)
Cross-platform	❌ No	Yes (Windows, Linux, macOS)

Optional: Ahead-of-Time (AOT) Compilation (Available in .NET Core/.NET 5+)

- .NET Core also supports **AOT Compilation** (like **Native AOT** in .NET 7).
- Compiles directly to native machine code **before** running.
- Improves startup time and reduces runtime overhead.

Summary

Step	Description
C# Code	Written by developer
Compilation	C# → IL (.dll or .exe)
Runtime (CLR/CoreCLR)	Converts IL → Native Machine Code
JIT or AOT	Executes on CPU
Result	Application runs, managed by runtime (memory, exceptions, threads)