CSC350

Using Async and Await

- Lecture will begin shortly
- Download class materials from university.xamarin.com

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Objectives

1. Introducing the **`async`** and **`await`** keywords
2. Applying **`async`** and **`await`**
3. Diving into the internals of **`async`** and **`await`**

Introducing the async and await keywords

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Tasks

1. Defining asynchronous programming
2. Explore available .NET options for asynchronous programming
3. Using the **`async`** and **`await`** keywords to simplify asynchronous programming

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What is asynchrony?

Synchronous vs. Asynchronous

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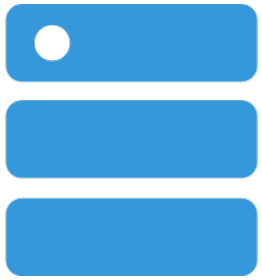
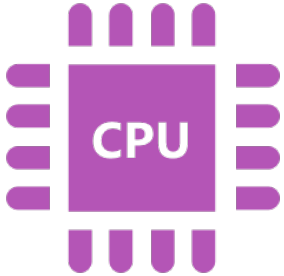
Why asynchronous programming?

- Asynchronous programming allows our mobile apps to continue to respond to user interaction while doing something else



Reading or writing to a database or file

Accessing a web service



Performing data processing

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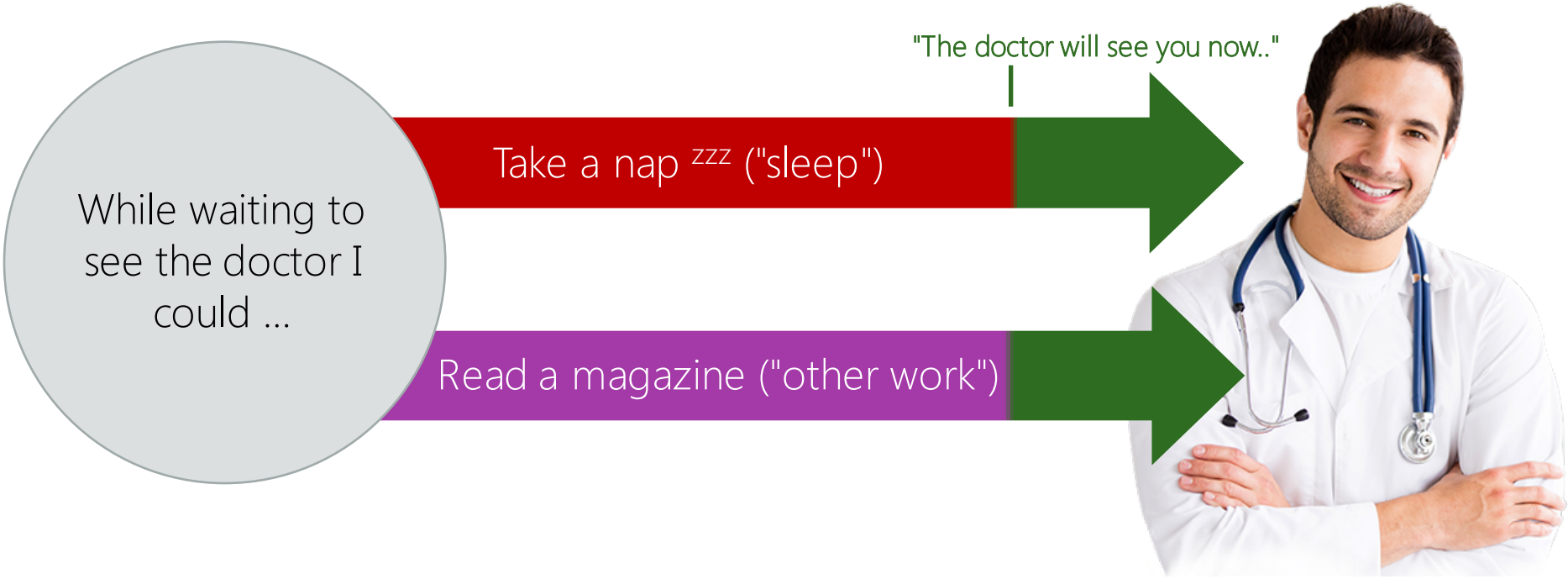
Thinking about asynchrony

- Asynchronous operations are started and then finish at some point in the future with a result … much like in the real world …



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Thinking about asynchrony

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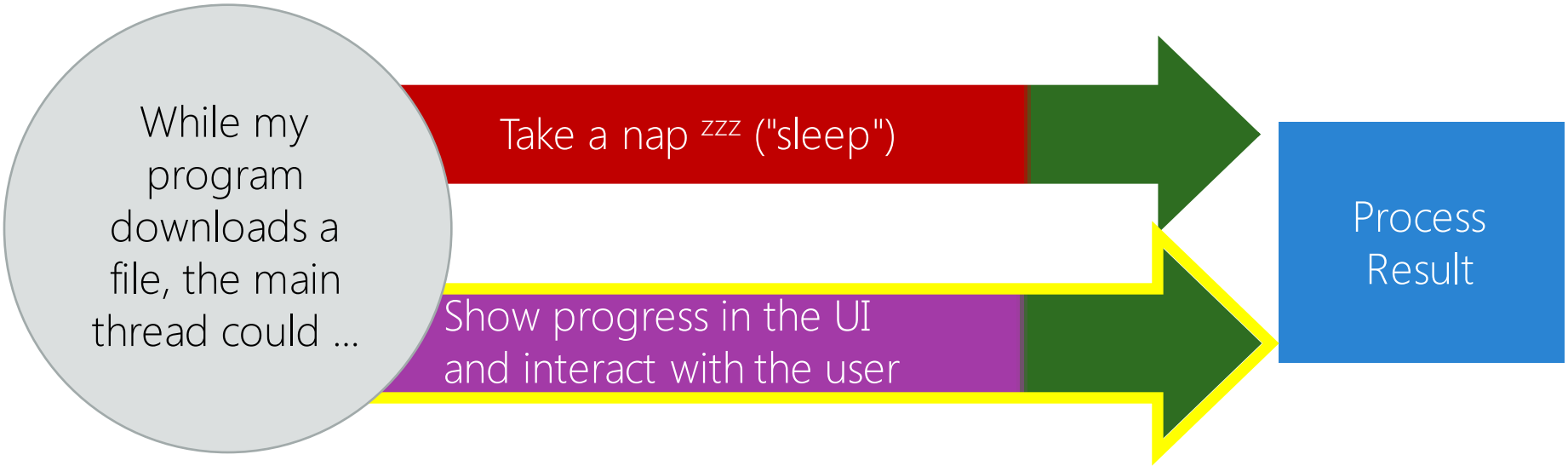

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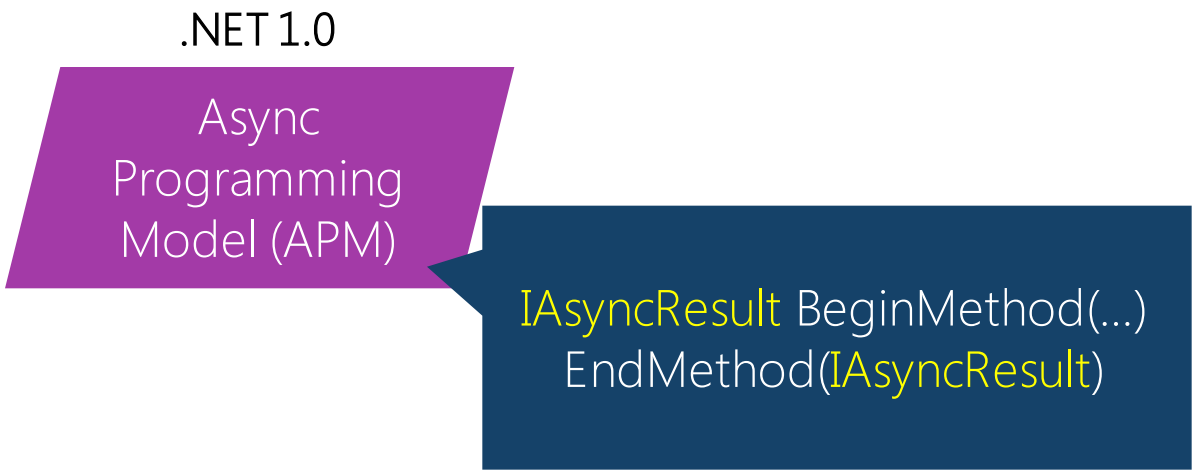
Async variations in .NET

- There are several asynchronous programming models to choose from:



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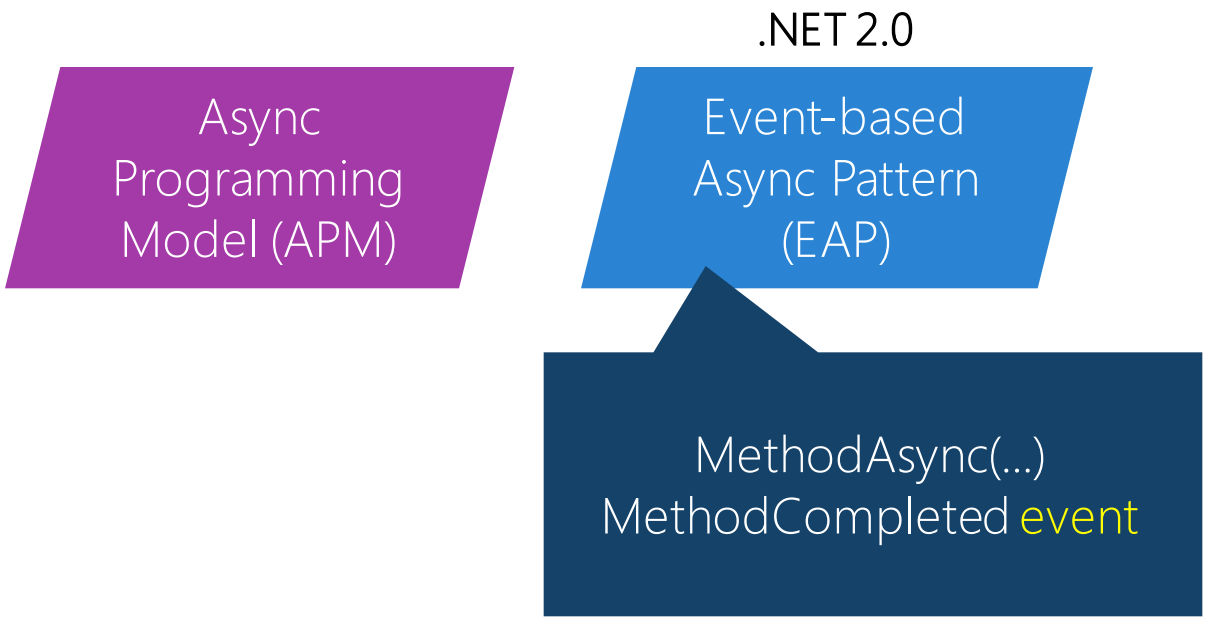
Async variations in .NET

- There are several asynchronous programming models to choose from:



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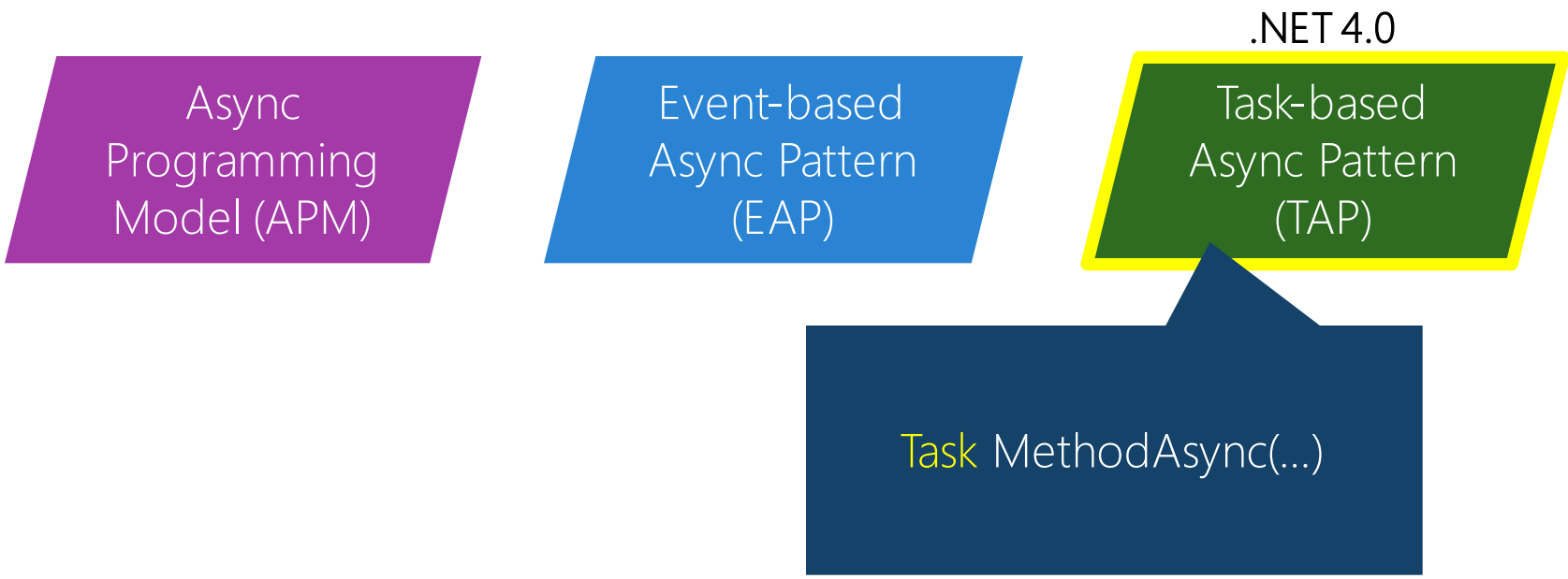
Async variations in .NET

- There are several asynchronous programming models to choose from:



Group Exercise

Use existing async APIs in an application

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The problem with async programming

- Prior to .NET 4.5, async programming was done through **callbacks** that forced developers to write code in a **non-linear** fashion

```
void OnReadDataFromUrl(object sender, EventArgs e)
{
    WebClient wc = new WebClient();
    wc.DownloadDataCompleted += (sender, e) => {
        if (e.Error == null) {
            var data = UTF8Encoding.GetString(e.Result);
            LoadData(data);
        }
    };
    wc.DownloadDataAsync(new Uri(url.Text));
}
```

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```
void OnReadDataFromUrl(object sender, EventArgs e)
{
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        if (e.Error == null) {
            var data = UTF8Encoding.GetString(e.Result);
            LoadData(data);
        }
    };
    wc.DownloadDataAsync(new Uri(url.Text));
}
```

Processing code is defined separately

The problem with async programming

- Prior to .NET 4.5, async programming was done through **callbacks** that forced developers to write code in a **non-linear** fashion

```
void OnReadDataFromUrl(object sender, EventArgs e)
{
    WebClient wc = new WebClient();
    wc.DownloadDataCompleted += (s
        if (e.Error == null) {
            var data = UTF8Encoding.GetString(e.Result);
            LoadData(data);
        }
    };
    wc.DownloadDataAsync(new Uri(url.Text));
}
```

Exceptions are reported in non-traditional fashion

The problem with async programming

- Prior to .NET 4.5, async programming was done through **callbacks** that forced developers to write code in a **non-linear** fashion

```
void OnReadDataFromUrl(object sender, EventArgs e)
{
    WebClient wc = new WebClient();
    wc.DownloadDataCompleted += (sender, e) => {
        if (e.Error == null) {
            var data = UTF8Encoding.GetString(e.Result);
            LoadData(data);
        }
    };
    wc.DownloadDataAsync(new Uri(url.Text));
}
```

Initiating method call is done *last*

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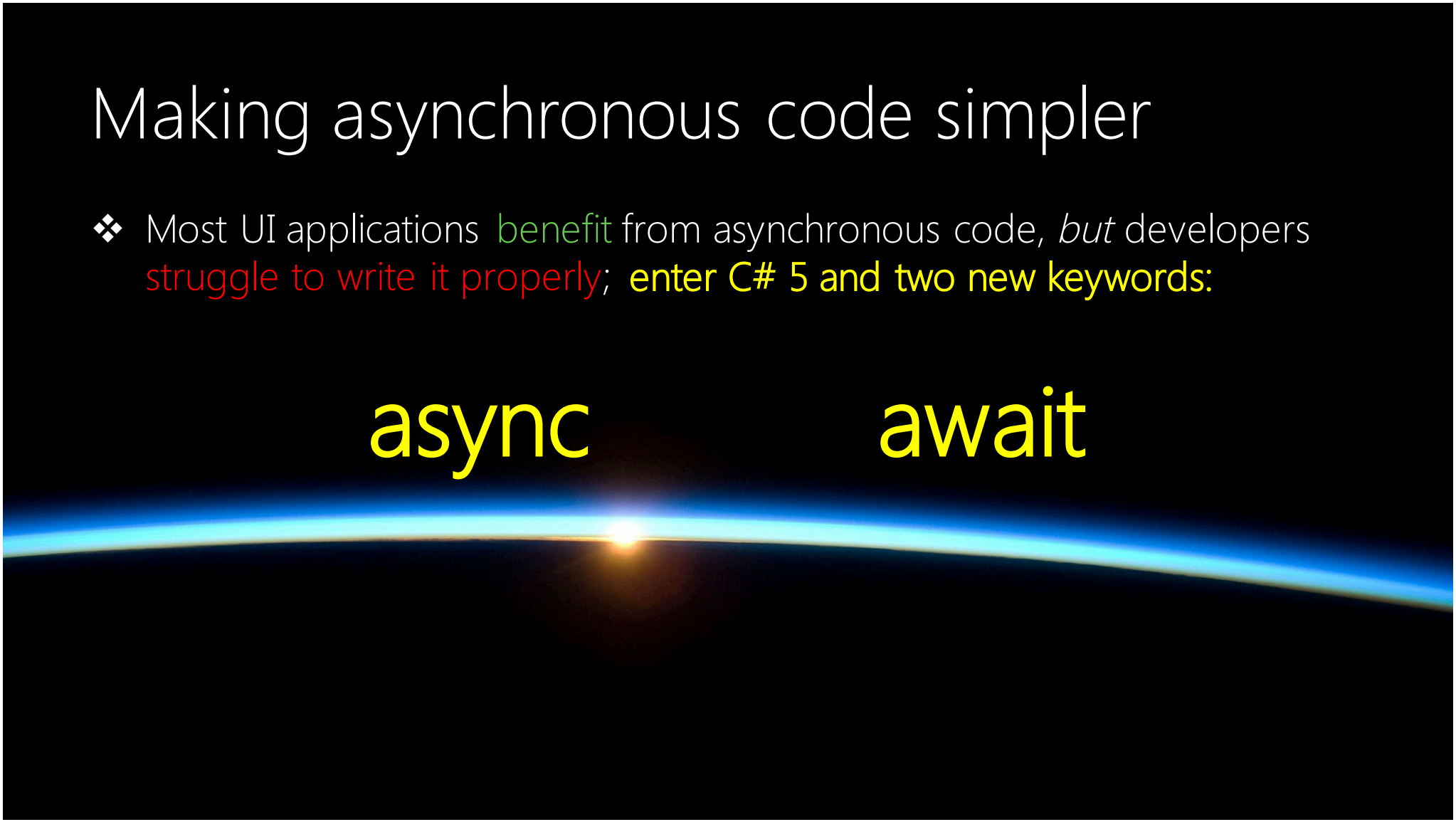
What we'd like to do...

- We want to write our code just as if it were going to be executed synchronously in step-by-step fashion ... like this:

```
void OnReadDataFromUrl(object sender, EventArgs e)
{
    WebClient wc = new WebClient();
    try {
        byte[] result = wc.DownloadData(new Uri(url.Text));
        var data = UTF8Encoding.GetString(result);
        LoadData(data);
    }
    catch (Exception ex) { ... }
}
```

Making asynchronous code simpler

- Most UI applications benefit from asynchronous code, *but* developers struggle to write it properly; enter C# 5 and two new keywords:



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The new world of async + await

- C# keywords allow developers to write code in a **synchronous fashion** but have it **run asynchronously**

```
async void OnReadDataFromUrl(object sender, EventArgs e)
{
    WebClient wc = new WebClient();
    try {
        byte[] result = await wc.DownloadData(new Uri(url.Text));
        var data = UTF8Encoding.GetString(result);
        LoadData(data);
    }
    catch (Exception ex) { ... }
}
```

Processing code is defined exactly where it should be – right after the call to get the data

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The new world of async + await

- C# keywords allow developers to write code in a **synchronous fashion** but have it **run asynchronously**

```
async void OnReadDataFromUrl(object sender, EventArgs e)
{
    WebClient wc = new WebClient();
    try {
        byte[] result = await wc.DownloadData(new Uri(url.Text));
        var data = UTF8Encoding.GetString(result);
        LoadData(data);
    }
    catch (Exception ex) { ... }
}
```

Errors are handled using traditional exception model

Demonstration

Look at async and await

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Summary

1. Defining asynchronous programming
2. Explore available .NET options for asynchronous programming
3. Using the **`async`** and **`await`** keywords to simplify asynchronous programming

Applying async and await

Tasks

1. What does the **`async`** keyword do?
2. Applying the **`await`** keyword
3. Working with awaitable expressions
4. Limitations of **`async`** and **`await`**

What does the async keyword do?

- The presence of **async** on a method allows the **await** keyword to be used in the method body, and indicates that some part of this method *can be executed asynchronously*

```
async void OnReadDataFromUrl(object sender, EventArgs e)
{
    ... // Now we can use await
}
```

Must be applied before the return type declaration on the method

Applying the await keyword

- The **await** keyword is applied to *awaitable expressions*

```
async void OnReadDataFromUrl(object sender, EventArgs e)
{
    WebClient wc = new WebClient();
    byte[] result = await wc.DownloadDataTaskAsync(
                                new Uri(url.Text));
...
```

An **awaitable** expression is an asynchronous operation, like this one that downloads data from a web endpoint

What does the await keyword do?

- Key idea behind **`await`** is to *pause* forward execution of the method until *after* the asynchronous operation is complete

```
async void OnReadDataFromUrl(object sender, EventArgs e)
{
    WebClient wc = new WebClient();

    byte[] result = await wc.DownloadDataTaskAsync(
                                        new Uri(url.T
    var data = UTF8Encoding.GetString(result);
    LoadData(data);
...
```

This code cannot execute until the data is downloaded

Using await in lambda expressions

- Can also use keywords in lambda expressions and anonymous delegates

must add `async` keyword onto the expression definition

```
button.Clicked += async (sender,e) =>
{
    HttpClient client = new HttpClient();
    string contents = await client.GetStringAsync(...);
    welcomeLabel.Text = contents.ToLower();
};
```

`await` keyword goes into the method body – but is still applied to the awaitable expression

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What is an awaitable expression?

- *Awaitable expressions* in .NET are methods that returns a **`Task`** or **`Task<T>`**; this is a framework class that represents an asynchronous request

```
public Task<byte[]> DownloadDataTaskAsync(string address);
```

Returning a task from a method call indicates that some portion of the method is performed asynchronously

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What is an awaitable expression?

- *Awaitable expressions* in .NET are methods that returns a **Task** or **Task<T>**; this is a framework class that represents an asynchronous request

```
public Task<byte[]> DownloadDataTaskAsync(string address);
```

Task<T> is a generic version of **Task** that returns a *promise*, or *future value* that will be available when the asynchronous operation completes

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What is an awaitable expression?

- *Awaitable expressions* in .NET are methods that returns a **`Task`** or **`Task<T>`**; this is a framework class that represents an asynchronous request

```
public Task<byte[]> DownloadDataTaskAsync(string address);
```

By convention, methods that are executed asynchronously always have the suffix **Async**

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Be careful: Await != Thread

- `await` does not create a thread, or even require a thread be used

```
async void LetsGoAsync(...) {
   Debug.WriteLine("1.. 2.. 3..");
   await TimerDelay(1000);
   Debug.WriteLine("Go!");
}

Task TimerDelay(int msec) { ... }
```

Possibly no additional thread is used here, but the two lines will be displayed 1 second apart; `await` is all about *coordination*, whether a thread is used or not is up to the awaitable expression

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Be careful: Await != Thread

- The awaitable expression must provide the asynchronous capability

```
async void button1_Click( ... )
{
    Action work = CPUWork;
    await RunWork(work);
}

Task RunWork(Action work)
{
    work();
}
```

CPUWork will be executed synchronously!

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Be careful: Await != Thread

- The awaitable expression must provide the asynchronous capability

```
async void button1_Click( ... )
{
    Action work = CPUWork;
    await RunWork(work);
}

Task RunWork(Action work)
{
    return Task.Run(() => work());
}
```

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Be careful: Await != Thread

- The awaitable expression must provide the asynchronous capability

```
async void button1_Click( ... )
{
    Action work = CPUWork;
    await RunWork(work);
}

Task RunWork(Action work)
{
    return Task.Run(() => work());
}
```

Flash Quiz

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Flash Quiz

① Which method definition is correct?

a) `void async ReadDataFromUrl(string url) { ... }`

b) `void await ReadDataFromUrl(string url) { ... }`

c) `async void ReadDataFromUrl(string url) { ... }`

d) `await void ReadDataFromUrl(string url) { ... }`

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Flash Quiz

① Which method definition is correct?

a) `void async ReadDataFromUrl(string url) { ... }`

b) `void await ReadDataFromUrl(string url) { ... }`

c) **`async void ReadDataFromUrl(string url) { ... }`**

d) `await void ReadDataFromUrl(string url) { ... }`

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Flash Quiz

② The `await` keyword can be applied to _____

a) any method call we want to run on a different thread
b) really fast code we want to slow down
c) methods that return a `Task` or `Task<T>`
d) All of the above

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Flash Quiz

② The **`await`** keyword can be applied to _____

a) any method call we want to run on a different thread

b) really fast code we want to slow down

c) methods that return a **`Task`** or **`Task<T>`**

d) All of the above

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Flash Quiz

③ In response to the **`await`** keyword, the C# compiler will create a thread

a) True

b) False

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Flash Quiz

③ In response to the **`await`** keyword, the C# compiler will create a thread

a) True

b) False

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Flash Quiz

④ The **`await`** keyword can only be applied to methods which return **`Task`**.

a) True

b) False

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Flash Quiz

④ The **`await`** keyword can only be applied to methods which return **`Task`**.

a) True

b) False

Summary

1. What does the **`async`** keyword do?
2. Applying the **`await`** keyword
3. Working with awaitable expressions
4. Limitations of **`async`** and **`await`**

Diving into the internals of async and await

Tasks

1. What does the **`await`** keyword do?
2. Exploring the generated code
3. Dealing with return values

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Execution progress for await

- At runtime, each **await** keyword starts the asynchronous operation and then **returns to the caller** because it cannot continue execution yet

```
async void OnClick(...)
{
    string url = ...;
✔   indicator.IsRunning = true;
    await ReadFromUrlAsync(url);
    indicator.IsRunning = false;
}
```

```
async Task ReadFromUrlAsync(string url)
{
✔   WebClient wc = new WebClient();

    byte[] result = await wc.DownloadDataTaskAsync(
                                        new Uri(url));

    var data = Encoding.ASCII.GetString(result);
    LoadData(data);
...
```

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Execution progress for await

- … then when the awaitable expression has a result, the runtime will **return to the method where it left off** to continue execution

```
async void OnClick(...)
{
    string url = ...;
✔   indicator.IsRunning = true;
✔   await ReadFromUrlAsync(url);
✔   indicator.IsRunning = false;
}
```

```
async Task ReadFromUrlAsync(string url)
{
✔   WebClient wc = new WebClient();

✔   byte[] result = await wc.DownloadDataTaskAsync(
                                    new Uri(url));

✔   var data = Encoding.ASCII.GetString(result);
✔   LoadData(data);
...
```

UI thread processes other UI events while waiting for the data to be downloaded

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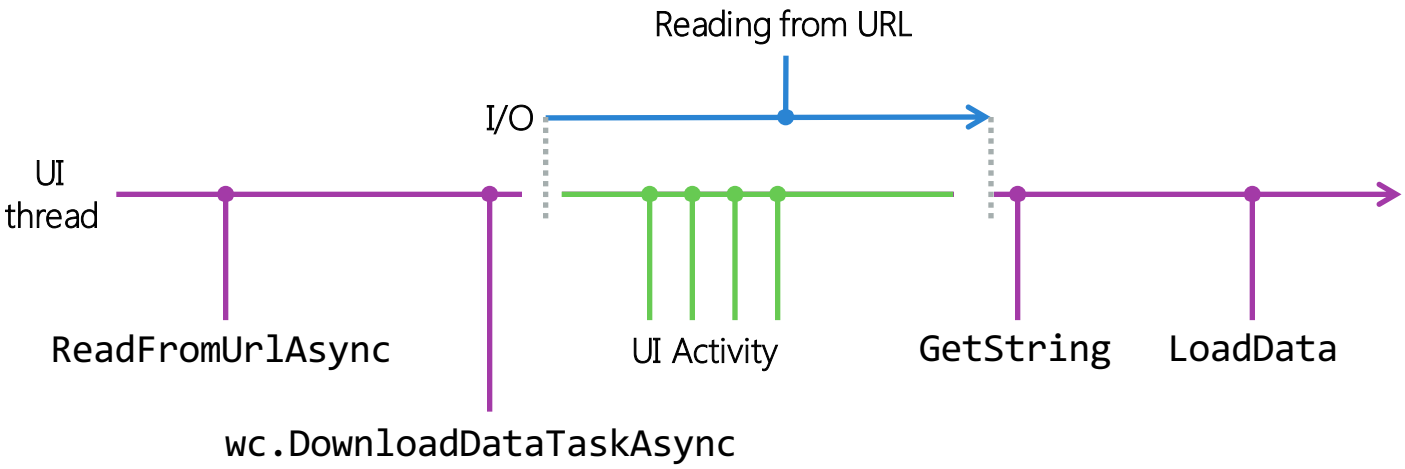
Execution progress for await

- … then when the awaitable expression has a result, the runtime will **return to the method where it left off** to continue execution



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How does await *really* work?

- Adding `async` changes how C# compiles the method and prepares it to support one or more asynchronous operations

```
public static void SayHello() {
  Console.WriteLine("Hello, World!");
}
```

```
.method public hidebysig static void SayHello() cil managed
{
    .maxstack 8
    L_0000: nop
    L_0001: ldstr "Hello, World!"
    L_0006: call void [mscorlib]System.Console::WriteLine(string)
    L_000b: nop
    L_000c: ret
}
```

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How does await *really* work?

- Adding `async` changes how C# compiles the method and prepares it to support one or more asynchronous operations

```
public static async void SayHello() {
  Console.WriteLine("Hello, World!");
}
```

All we've done is add the `async` keyword to the method… but look what changes in the IL:

```
.method public hidebysig static void SayHello() cil managed
{
  .maxstack 2
  .locals init ([0] class Test.Program/<SayHello>d__1 d__)
  IL_0000:  ldloca.s   V_0
  IL_0002:  call       valuetype [mscorlib]System.Runtime.CompilerServic
[mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder::Create
  IL_0007:  stfld      valuetype [mscorlib]System.Runtime.CompilerServic
Program/'<SayHello>d__1'::'<>t__builder'
  IL_000c:  ldloca.s   V_0
  IL_000e:  call       instance void Program/'<SayHello>d__1'::MoveNext()
  IL_0013:  ret
}
```

New compiler-generated class introduced to manage any asynchronous code

Method body is compiled as a series of "steps"; similar to iterator methods

```
.method public hidebysig static void SayHello() cil managed
{
  .maxstack 2
  .locals init ([0] class Test.Program/<SayHello>d__1 d__)
  IL_0000:  ldloca.s   V_0
  IL_0002:  call       valuetype [mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder
[mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder::Create()
  IL_0007:  stfld      valuetype [mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder
Program/'<SayHello>d__1'::'<>t__builder'
  IL_000c:  ldloca.s   V_0
  IL_000e:  call       instance void Program/'<SayHello>d__1'::MoveNext()
  IL_0013:  ret
}
```

async methods always return after **MoveNext** is finished

```
.method public hidebysig static void SayHello() cil managed
{
  .maxstack 2
  .locals init ([0] class Test.Program/<SayHello>d__1 d__)
  IL_0000:  ldloca.s   V_0
  IL_0002:  call       valuetype [mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder
[mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder::Create()
  IL_0007:  stfld      valuetype [mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder
Program/'<SayHello>d__1'::'<>t__builder'
  IL_000c:  ldloca.s   V_0
  IL_000e:  call       instance void Program/'<SayHello>d__1'::MoveNext()
  IL_0013:  ret
}
```

```
.method private hidebysig newslot virtual final instance void MoveNext() cil managed
{
  .override [mscorlib]System.Runtime.CompilerServices.IAsyncStateMachine::MoveNext
  .maxstack 2
  .locals init ([0] int32 num, [1] class [mscorlib]System.Exception exception)
  L_0000: ldarg.0
  L_0001: ldfld int32 Test.Program/<SayHello>d__1::<>1__state
  L_0006: stloc.0
  L_0008: ldstr "Hello, World!"
  L_000d: call void [mscorlib]System.Console::WriteLine(string)
  L_0013: leave.s
  ...
}
```

Tracks the current "state" of this async method

```
.method public hidebysig static void SayHello() cil managed
{
  .maxstack 2
  .locals init ([0] class Test.Program/<SayHello>d__1 d__)
  IL_0000:  ldloca.s   V_0
  IL_0002:  call       valuetype [mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder
[mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder::Create()
  IL_0007:  stfld      valuetype [mscorlib]System.Runtime.CompilerServices.AsyncTaskMethodBuilder
Program/'<SayHello>d__1'::'<>t__builder'
  IL_000c:  ldloca.s   V_0
  IL_000e:  call       instance void Program/'<SayHello>d__1'::MoveNext()
  IL_0013:  ret
}
```

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  L_0006: stloc.0
  L_0008: ldstr "Hello, World!"
  L_000d: call void [mscorlib]System.Console::WriteLine(string)
  L_0013: leave.s
  ...
}
```

Always captures exceptions – even if you didn't ask it to!

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The secret behind await

- Under the covers, the compiler turns the method into a *state machine* in anticipation of having portion(s) be executed in steps

```
async void ReadDataFromUrl(string url)
{
   WebClient wc = new WebClient();
   var result = await wc.DownloadDataTaskAsync(url);
   var data = Encoding.ASCII.GetString(result);
   LoadData(data);
}
```

All of the variables in the method are captured as fields in the state machine and used to manage the local state

```
[CompilerGenerated]
private sealed class <ReadDataFromUrl>d__1 : IAsyncStateMachine
{
  // Fields
  public int <>1__state;
  private byte[] <>s__4;
  public AsyncVoidMethodBuilder <>t__builder;
  private TaskAwaiter<byte[]> <>u__1;
  private string <data>5__3;
  private byte[] <result>5__2;
  private WebClient <wc>5__1;
  public string url;

  // Methods
  public <ReadDataFromUrl>d__1();
  private void MoveNext();
  [DebuggerHidden]
  private void SetStateMachine(IAsyncStateMachine stateMachine);
}
```

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What's in MoveNext?

- State Machine is coded into a **`MoveNext`** method which is called for each step and tracks an integer state to execute the code

```
async void ReadDataFromUrl(string url)
{
    WebClient wc = new WebClient();
    var result = await wc.DownloadDataTaskAsync(url);
    var data = Encoding.ASCII.GetString(result);
    LoadData(data);
}
```

1. Create the **`WebClient`** and issue the download async request

```
public void MoveNext()
{
    uint num = (uint)this.$PC;
    this.$PC = -1;
    try {
        switch (num) {
            case 0:
                this.<wc>__0 = new WebClient();
                this.$awaiter0 = this.<wc>                    .url).GetAwaiter();
                this.$PC = 1;
                ...
                return;
                break;
            case 1:
                this.<result>__1 = this.$awaiter0.GetResult();
                this.<data>__2 = Encoding.ASCII.GetString(this.<result>__1);
                this.$this.LoadData(this.<data>__2);
                break;
            default:
                return;
        }
    }
    catch (Exception exception) { ... }
    this.$PC = -1;
    this.$builder.SetResult();
}
```

Move to next state

What's in MoveNext?

- State Machine is coded into a **`MoveNext`** method which is called for each step and tracks an integer state to execute the code

```
async void ReadDataFromUrl(string url)
{
    WebClient wc = new WebClient();
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    var data = Encoding.ASCII.GetString(result);
    LoadData(data);
}
```

1. Create the **`WebClient`** and issue the download async request

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public void MoveNext()
{
    uint num = (uint)this.$PC;
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    try {
        switch (num) {
            case 0:
                this.<wc>__0 = new WebClient();
                this.$awaiter0 = this.<wc>__0.DownloadDataTaskAsync(this.url).GetAwaiter();
                this.$PC = 1;
                ...
                return;
                break;
            case 1:
                this.<result>__1 = th
                this.<data>__2 = Enco                    ult>__1);
                this.$this.LoadData(this.<data>__2);
                break;
            default:
                return;
        }
    }
    catch (Exception exception) { ... }
    this.$PC = -1;
    this.$builder.SetResult();
}
```

Notice the return!

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What's in MoveNext?

- State Machine is coded into a **`MoveNext`** method which is called for each step and tracks an integer state to execute the code

```
async void ReadDataFromUrl(string url)
{
    WebClient wc = new WebClient();
    var result = await wc.DownloadDataTaskAsync(url);
    var data = Encoding.ASCII.GetString(result);
    LoadData(data);
}
```

2 Process the results from the async call

```
public void MoveNext()
{
    uint num = (uint)this.$PC;
    this.$PC = -1;
    try {
        switch (num) {
            case 0:
                this.<wc>__0 = new WebClient();
                this.$awaiter0 = this.<wc>__0.DownloadDataTaskAsync(this.url).GetAwaiter();
                this.$PC = 1;
                ...
                return;
                break;
            case 1:
                this.<result>__1 = this.$awaiter0.GetResult();
                this.<data>__2 = Encoding.ASCII.GetString(this.<result>__1);
                this.$this.LoadData(this.<data>__2);
                break;
            default:
                return;
        }
    }
    catch (Exception exception) { ... }
    this.$PC = -1;
    this.$builder.SetResult();
}
```

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- State Machine is coded into a **`MoveNext`** method which is called for **each step** and tracks an integer state to execute the code

```
async void ReadDataFromUrl(string url)
{
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   var result = await wc.DownloadDataTaskAsync(url);
   var data = Encoding.ASCII.GetString(result);
   LoadData(data);
}
```

3 Catches all exceptions. This is done even if your method does not have a **`try`** / **`catch`** handler and is how **`await`** is able to re-throw them in the client code

```
public void MoveNext()
{
   uint num = (uint)this.$PC;
   this.$PC = -1;
   try {
      switch (num) {
         case 0:
            this.<wc>__0 = new WebClient();
            this.$awaiter0 = this.<wc>__0.DownloadDataTaskAsync(this.url).GetAwaiter();
            this.$PC = 1;
            ...
            return;
            break;
         case 1:
            this.<result>__1 = this.$awaiter0.GetResult();
            this.<data>__2 = Encoding.ASCII.GetString(this.<result>__1);
            this.$this.LoadData(this.<data>__2);
            break;
         default:
            return;
      }
   }
   catch (Exception exception) { ... }
   this.$PC = -1;
   this.$builder.SetResult();
}
```

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① The **`await`** keyword causes the current thread to block waiting for the asynchronous operation to complete

a) True

b) False

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① The **`await`** keyword causes the current thread to block waiting for the asynchronous operation to complete

a) True

b) False

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Flash Quiz

② Adding **`async`** to a method definition doesn't change anything until the **`await`** keyword is used

a) True

b) False

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Flash Quiz

② Adding **`async`** to a method definition doesn't change anything until the **`await`** keyword is used

a) True

b) False

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Flash Quiz

③ What side effects does using `async/await` always have on a method? (Select all that apply)

a) The method will be broken into multiple steps

b) Exceptions will be caught, and *possibly* re-thrown

c) Local variables will be captured and moved to the GC heap

d) It will cause the method to use multiple threads

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Flash Quiz

③ What side effects does using `async/await` always have on a method? (Select all that apply)

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d) It will cause the method to use multiple threads

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Leaking abstractions

- Notice that the value being **consumed** and the value being **returned** are not quite the same

```
byte[] result = await wc.DownloadDataTaskAsync( ... );
```

Compiler interprets the `await` keyword to mean "get the result from the task"

```
public Task<byte[]> DownloadDataTaskAsync(string address);
```

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Dealing with return values

- This becomes evident in the return value from methods that *use* `await`

```
async string ReadDataFromUrl(string url)   The return type of an async method must be void, Task, or Task<T>
{
    WebClient wc = new WebClient();
    byte[] result = await wc.DownloadDataTaskAsync(url);
    string data = Encoding.ASCII.GetString(result);
    return data;
}
```

What are we returning here?
Or perhaps a better question is *where are we returning from this method?*

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Dealing with return values

- This becomes evident in the return value from methods that *use* `await`

```
async string ReadDataFromUrl(string url)
{
    WebClient wc = new WebClient();
    byte[] result = await wc.DownloadDataTaskAsync(url);
    string data = Encoding.ASCII.GetString(result);
    return da
}
```

The method is *really* returning to the caller **here** – before we ever hit an actual return keyword .. What must this return?

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Returning a "future" value

- `Task<T>` represents a "future" value – something that will eventually produce either a value or exception; this is what we must return from the method in order for the compiler to produce legitimate code

```
async Task<string> ReadDataFromUrl(string url)
{
    WebClient wc = new WebClient();
    var result = await wc.DownloadDataTaskAsync(url);
    string data = Encoding.ASCII.GetString(result);
    return data;
}
```

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Valid return values for async methods

- Since **await**ed methods return before the entire method is complete, they must have a **specific return type**, one of three valid values:

`Task<T>` if it returns a value

```
async Task<double> CalculatePiAsync()
```

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Valid return values for async methods

- Since `await`ed methods return before the entire method is complete, they must have a **specific return type**, one of three valid values:

`Task<T>` if it returns a value

`Task` for no return value (e.g. *void*)

```
async Task WriteToLogAsync(...)
```

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Valid return values for async methods

- Since **`await`**ed methods return before the entire method is complete, they must have a **specific return type**, one of three valid values:

`Task<T>` if it returns a value	`Task` for no return value (e.g. *void*)	`void` for event handlers

```
async void OnClick(...)
```

Beware void returns

- You cannot `await` a `void`-return async method since they don't return a `Task`
- Without an `await`, you cannot catch any exceptions that occur in the task
- You should **never** use a `void`-return async method *unless* it's an event handler, or a virtual method override where you have no choice

Individual Exercise

Convert app to use async and await

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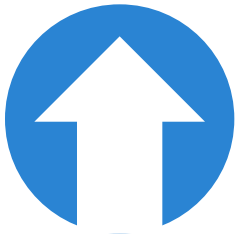
Async / Await limitations

- Several restrictions placed on `async` / `await` usage by the compiler



No `out` or `ref` parameters

Return complex types from the Task instead – such as `Tuple<T1,T2>`

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Async / Await limitations

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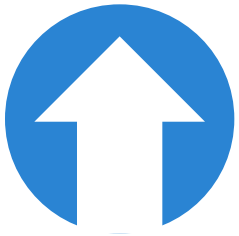

No `out` or `ref` parameters

Cannot use in constructors or property getters

Ctors and properties must return an immediate value, which is not possible

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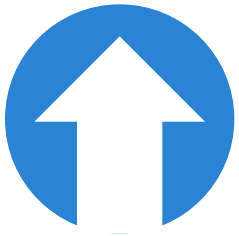
Async / Await limitations

- Several restrictions placed on `async` / `await` usage by the compiler



No `out` or `ref` parameters

Cannot use in constructors or property getters

Not allowed while in sync block (`lock`)

Can use different synchronization mechanism, or restructure code

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Async / Await limitations

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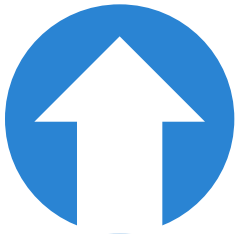

No `out` or `ref` parameters

Cannot use in constructors or property getters

Can only use await in first select or group

Not allowed while in sync block (`lock`)

Limited support in LINQ queries

Summary

1. What does the **`await`** keyword do?
2. Exploring the generated code
3. Dealing with return values

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Where are we going from here?

- Async / Await are really nice ways to provide a convenient structure for *consuming* async code
- Next we will look at how to *write* async code using the Task Parallel Framework in **CSC351**

Thank You!

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