WELCOME TO

PARTSTRADER

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Welcome to PartsTrader

- Where is the food?
- Where are the restrooms?
- What does PartsTrader do?
- Who is talking to us?
- Who else is here?

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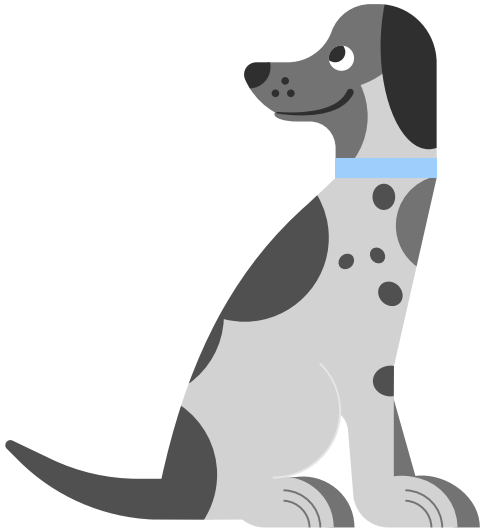
NULLWORRIES

(BE HAPPY)

Overview

- Why do we use null?
- How does it cause problems?
- What can we do about it?



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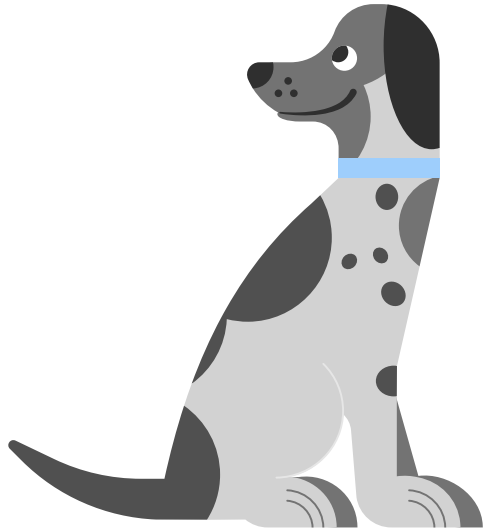
Why do we use null?

We use null to represent:

- the *absence* of a value, or
- an *unspecified* value.



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Absence of a value

The *absence* of a value represents:

- an *unknown* value, or
- an *unnecessary* value.

```
public class Person
{
    public Person(string givenName, string familyName)
    …
}

// Jane Citizen
Person a = new (“Jane”, “Citizen”);

// John ?
Person b = new(“John”, null);

// Lorde
Person c = new(“Lorde”, null);
```

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Unspecified value

An *unspecified value* represents:

- an *invalid* value, or
- a *choice* to omit a value.

```
public class Person
{
    public Person(DateTime? dateOfBirth)
    {
        DateOfBirth = dateOfBirth != null &&
            dateOfBirth.Value < DateTime.Now
                ? dateOfBirth : null;
    }

    public DateTime? DateOfBirth { get; }
}

Person a = new(DateTime.Parse(“3000-04-01”));

Person b = new(null);
```

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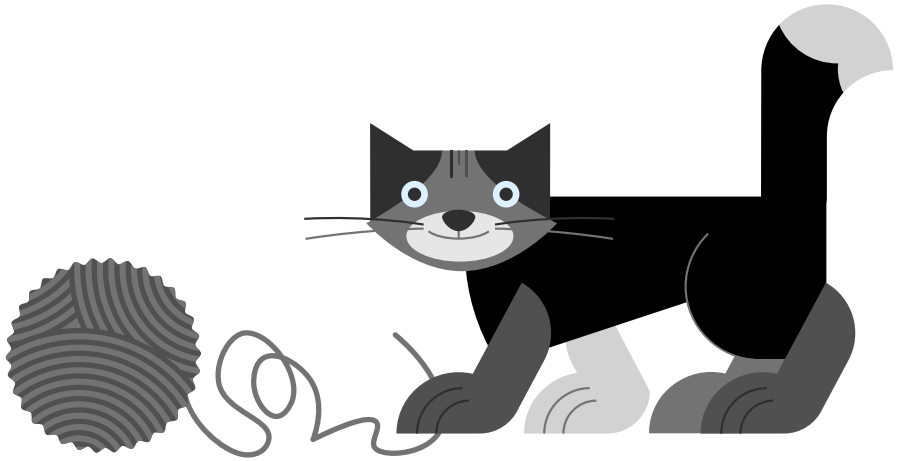
How does it cause problems?

Null causes problems due to:

- uncertainty, and
- null references.



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Uncertainty

It is not clear if *null* represents:

- an *unknown* value,
- an *unnecessary* value,
- an *invalid* value, or
- a *choice* to omit a value.

```
public class DateRange
{
    public DateRange(DateTime? start, DateTime? end)
    {
        Start = start
        End = end
    }

    public DateTime? Start { get; }
    public DateTime? End { get; }
}

// what does this mean?
DateRange range = new(null, null);
```

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What is a null reference?

A reference points to *something* in memory.

```
// reference to object
object obj = new();

// reference to string
var str = “Hello world!”;
```

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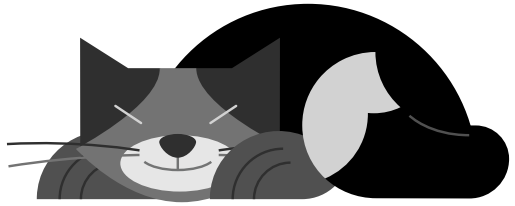
What is a null reference?

A reference points to *something* in memory.

A null reference points at *nothing*.



```
// reference to object
object obj = new();

// reference to string
var str = “Hello world!”;

// null reference
object obj = null;
```

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Is that a problem?

Tony Hoare invented Quicksort in 1959.

In 1965, he invented null references.

He apologised for them in 2009…

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Why did he do that?

"I call it my billion dollar mistake"

"I couldn't resist the temptation to put in a null reference, because it was so easy to implement"

"This has led to innumerable errors, vulnerabilities and system crashes"

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What is the problem?

~~Developers are lazy~~

Developers are human, and make mistakes

It is *very easy* to forget to check for null references

```
var obj = GetObject();
var text = obj.ToString();

var n = text.Length;

Regex pattern = new (@"^\\d{4,}$");
var isMatch = pattern.IsMatch(text);
```

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null-worries/src/easy-to-forget

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What happens if we forget?

For .NET, invoking a member on a null reference:

- will cause a *NullReferenceException*,
- will abort the current operation,
- may cause data/state corruption, and
- may terminate the application.

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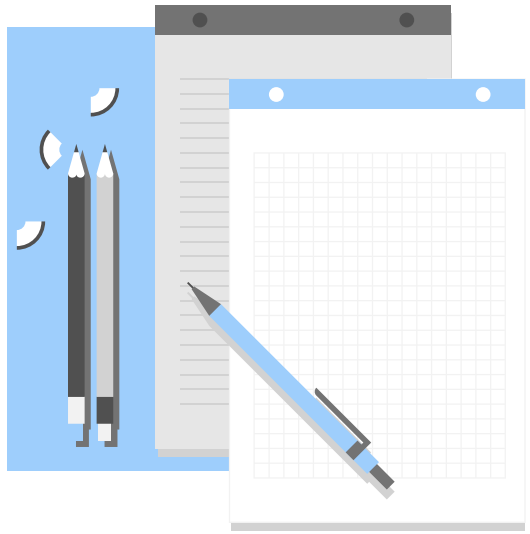
What can we do about it?

Null worries? Be happy with:

- alternatives to null,
- ensuring valid object state,
- C# language features, and
- functional programming.



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Default objects

If object not found, then return:

- null.

```
public class Person
{
    public static Person GetPerson(int id)
    {
        // not found
        return null;
    }
}

var person = Person.GetPerson(1);

// exception: person is null
var text = person.ToString();
```

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null-worries/src/default-objects

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Default objects

If object not found, then return:

- ~~null.~~
- a default object.

```
public class Person
{
    public static readonly Person Unknown = new();

    public static Person GetPerson(int id)
    {
        // not found
        return Unknown;
    }
}

var person = Person.GetPerson(1);

// no exception
var text = person.ToString();
```

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Are default objects practical?

Advantages:

- null worry eliminated.

Disadvantages:

- non-standard code, and
- easy to forget about.

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Enforce valid object state

If an object is initialised with an invalid state, then:

- keep calm and carry on.

```
public class Book
{
    public Book(string title)
    {
        Title = title;
    }

    public string Title { get; }
}

// no exception
Book book = new(null);

// exception: Title is null
var searchTerm = “the”;
var isMatch = book.Title.Contains(searchTerm);
```

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null-worries/src/valid-state

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Enforce valid object state

If an object is initialised with an invalid state, then:

- ~~keep calm and carry on.~~
- fail fast.

```
public class Book
{
    public Book(string title)
    {
        Title = title ?? throw new
            ArgumentNullException(nameof(title));
    }

    public string Title { get; }
}

// exception: fail fast
Book a = new(null);

// no exception
Book b = new("Screens");
```

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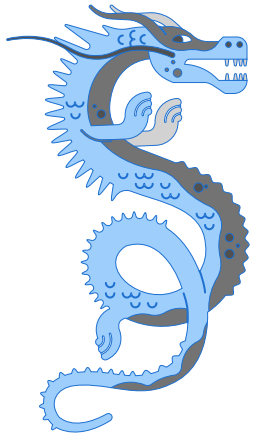
Beware of value types

Value types in C# always have a default constructor!



```
public struct Book
{
    public Book(string title)
    {
        Title = title ?? throw new
            ArgumentNullException(nameof(title));
    }

    public string Title { get; }
}

// has a default constructor!
Book book = new();

// exception: Title is null
var searchTerm = "the";
var isMatch = book.Title.Contains(searchTerm);
```

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null-worries/src/valid-state

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Enforce valid object state

If a choice exists between memory and state, then:

- choose memory.

```
public class Author
{
    public Author()
    {
        // use default initializers
    }

    public Author(IEnumerable<Book> books)
    {
        Books = books ?? throw new
            ArgumentNullException(nameof(books));
    }

    public IEnumerable<Book> Books { get; };
}

Author author = new();

// exception: Books is null
var hasBooks = author.Books.Any();
```

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null-worries/src/valid-state

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Enforce valid object state

If a choice exists between memory and state, then:

- ~~choose memory.~~
- choose valid object state.

```
public class Author
{
    public Author()
    {
        Books = Enumerable.Empty<Book>();
    }

    public Author(IEnumerable<Book> books)
    {
        Books = books ?? throw new
            ArgumentNullException(nameof(books));
    }

    public IEnumerable<Book> Books { get; };
}

Author author = new();

// no exception
var hasBooks = author.Books.Any();
```

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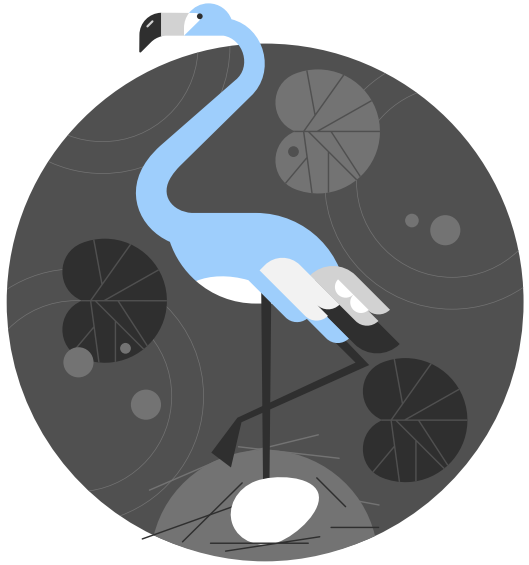
Is enforcing state practical?

Disadvantages:

- failures will happen.

Advantages:

- known failure points, and
- principal of least surprise.



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Use setters to enforce state

If a property is set to an invalid state, then:

- keep calm and carry on.

```
public class Book
{
    public Book(string title)
    {
        Title = title;
    }

    public string Title { get; set; }
}

// no exception
Book book = new("Screens");
book.Title = null;

// exception: Title is null
var searchTerm = "the";
var isMatch = book.Title.Contains(searchTerm);
```

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Use setters to enforce state

If a property is set to an invalid state, then:

- ~~keep calm and carry on.~~
- fail fast.

```
public class Book
{
    public Book(string title)
    {
        Title = title;
    }

    private string _title;
    public string Title
    {
        get => _title;
        set => _title = value ?? throw new
            ArgumentNullException(nameof(title));
    }
}

Book book = new("Screens");

// exception: fail fast
Book.Title = null;
```

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Is enforcing state with setters practical?

Advantages:

- known failures points.

Disadvantages:

- additional failure points, and
- greater chance of surprises.

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Mutable and immutable types

The value of a *mutable* type *can* be changed

```
public class Author
{
    public Author(string name)
    {
        Name = name;
    }

    public string Name { get; set; }
}

Author author = new("Christopher Laine");

// value can be changed
author.Name = "Peter F. Hamilton";
```

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Mutable and immutable types

The value of a *mutable* type *can* be changed.

The value of an *immutable* type *cannot* be changed.

```
public class Author
{
    public Author(string name)
    {
        Name = name;
    }

    public string Name { get; }
}

Author author = new("Christopher Laine");

// compiler error: value cannot be changed
author.Name = "Peter F. Hamilton";
```

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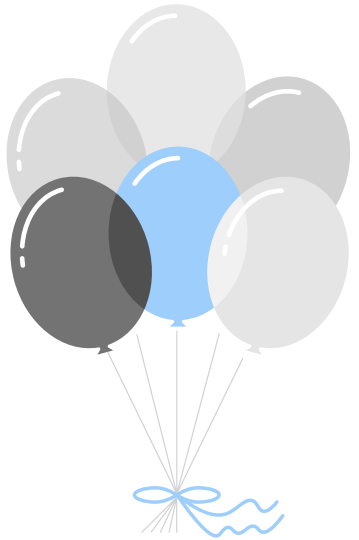
Advantages of immutable types

- Enforce valid object state with constructors
- Safer multi-threading:
  - ✓ Cannot be changed by other threads
  - ✓ Does not require synchronisation
- WYSIWYG: principle of least surprise



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Disadvantages of immutable types

- ~~Greater memory usage~~
- Can be painful to initialise

```
public class Book
{
    public Book(
        string title,
        string isbn,
        string subject,
        decimal retailPrice,
        Author author,
        IEnumerable<Review> reviews,
        …)
    {
        // TODO: validate every argument...
    }
}
```

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Playing together: the builder pattern

The builder pattern:

- allows bit-by-bit initialisation,
- guides us through it, and
- can build an immutable type.

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Start with a part

- Immutable type
- Not enforcing valid state
- Internal constructor
- Not a value type

```
public class Part
{
    internal Part(
        string partNumber,
        string description,
        decimal listPrice)
    {
        PartNumber = partNumber;
        Description = description;
        ListPrice = listPrice;
    }

    public string PartNumber { get; }

    public string Description { get; }

    public decimal ListPrice { get; }
}
```

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null-worries/src/builders

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Scaffold the part builder

Required:

- part number, and
- list price.

Optional:

- description.

```
public class PartBuilder
{
    private string _partNumber;
    private string _description;
    private decimal _listPrice;

    public PartBuilder()
    {
        _description = string.Empty;
    }
}
```

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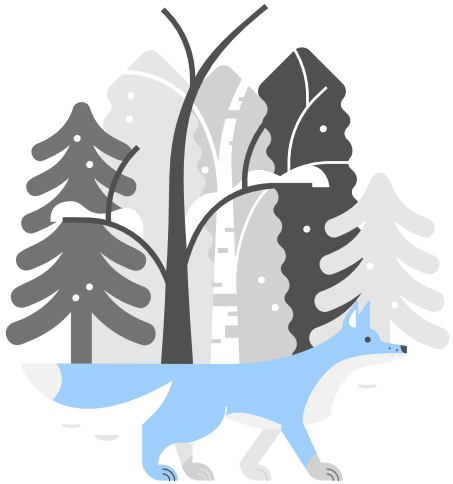
Begin at the end

- Explicit interface implementation



```
public interface IListPriceInitialized
{
    Part Build();
}

public class PartBuilder : IListPriceInitialized
{
    Part IListPriceInitialized.Build() =>
        new(_partNumber, _description, _listPrice);
}
```

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A required list price

- Code omitted for clarity
- Enforcing valid state
- Returns available actions

```
public interface IDescriptionInitialized
{
    IListPriceInitialized ListPrice(decimal listPrice);
}

public class PartBuilder : IDescriptionInitialized, …
{
    IListPriceInitialized
        IDescriptionInitialized.ListPrice(
            decimal listPrice)
    {
        if (listPrice < 0m)
        {
            throw new ArgumentOutOfRangeException(…);
        }

        _listPrice = listPrice;

        return this;
    }
}
```

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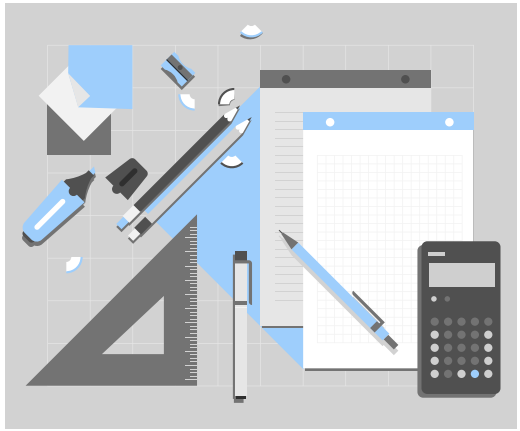
An optional description

What happens if *null* is passed for the description?



```
public interface IPartNumberInitialized :
    IDescriptionInitialized
{
    IDescriptionInitialized Description(
        string description);
}

public class PartBuilder : IPartNumberInitialized, …
{
    IDescriptionInitialized
        IPartNumberInitialized.Description(
            string description)
    {
        if (string.IsNullOrWhiteSpace(description))
        {
            throw new ArgumentException(…);
        }

        _description = description;

        return this;
    }
}
```

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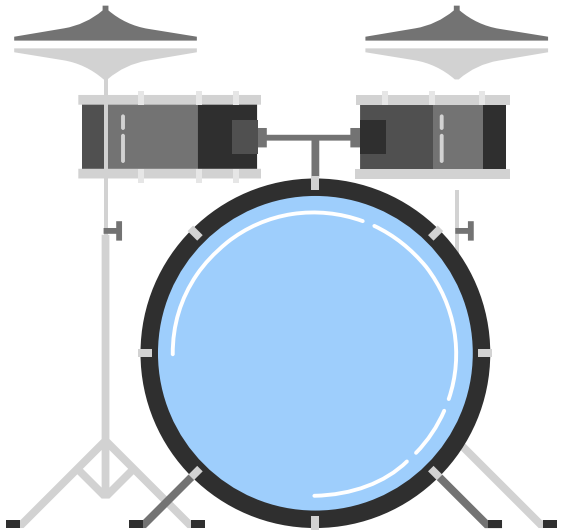
A required part number



```
public interface IUninitialized
{
    IPartNumberInitialized PartNumber(
        string partNumber);
}

public class PartBuilder : IUninitialized, …
{
    public IPartNumberInitialized PartNumber(
        string partNumber)
    {
        if (string.IsNullOrWhiteSpace(partNumber))
        {
            throw new ArgumentException(…);
        }

        _partNumber = partNumber;

        return this;
    }
}
```

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What have we got?

- ✓ Bit-by-bit initialisation
- ✓ Guides us through it
- ✓ Creates immutable type
- ✓ Enforces valid object state

```
// with description
var a = new PartBuilder()
    .PartNumber("1234-abcd")
    .Description("Sample Part")
    .ListPrice(12.95)
    .Build();

// no description
var b = new PartBuilder()
    .PartNumber("5678-efgh")
    .ListPrice(3.14)
    .Build();

// compiler error
var c = new PartBuilder()
    .PartNumber("1234-abcd")
    .Build();
```

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C# language features

- Nullable reference types (C# 8)
- Records (C# 9)
- Init-only setters (C# 9)
- Null parameter checking (C# 10)*
- Required properties (C# 10) *

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Nullable reference types

- C# 8 (.NET Core 3.x)
- Same syntax as value type
- Used to indicate when a reference can be *null*

```
// value type
int a = 0;

// nullable value type
int? b = null;

// “non-nullable” reference type
object c = new object();

// nullable reference type
object? d = null;
```

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Disabled by default

- Edit project file
- Add <Nullable> element
- Set to *enable*

```
<Project Sdk="Microsoft.NET.Sdk">
  <PropertyGroup>
    <Nullable>enable</Nullable>
  </PropertyGroup>
</Project>
```

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null-worries/src/nullable-references

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How does it help?

- Shows a warning if a reference can be null
- Reveals unexpected edge cases in old code
- Suggestion: treat warnings as errors

```
// valid: can be null
object? a = null;

// invalid: cannot be null
object? b = null;

object obj = new();
var text = obj.ToString();

// CS8602 Dereference of a possibly null reference
var n = text.Length;

if (text != null)
{
    // no warning: text is non-null
    var m = text.Length;
}
```

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Records

- C# 9 (.NET 5.x)
- Automatic properties
- Does *not* automatically enforce valid object state
- Does automatically give Equals, ToString, etc…

```
// class
public class Person
{
    public Person(string givenName, string familyName)
    {
        GivenName = givenName;
        FamilyName = familyName;
    }

    public string GivenName { get; }

    public string FamilyName { get; }
}

// record
public record Person
{
    public Person(string GivenName, string FamilyName);
}
```

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Init-only setters

- C# 9 (.NET 5.x)
- Immutable properties
- Optional initialization only
- Use a backing field to enforce property state

```
public class Part
{
    public string PartNumber { get; init; }

    public string Description { get; init; }

    public decimal ListPrice { get; init; }
}

Part part = new
{
    PartNumber = "1234-abcd",
    ListPrice = 12.95
};

// compiler error
part.Description = "Sample Part";
```

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Null parameter checking

- C# 10 (.NET 6.x)*
- Prototype feature/syntax
- Only checks for *null*

```
// manual
public Book(string title)
{
    if (title == null)
    {
        throw new ArgumentNullException(…);
    }
    …
}

// automatic
public Book(string title!!)
{
    …
}
```

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Required properties

- C# 10 (.NET 6.x)*
- Prototype feature/syntax
- Use backing fields to enforce valid object state

```
public class Part
{
    public required string PartNumber { get; init; }

    public string Description { get; init; }

    public required decimal ListPrice { get; init; }
}

// compiler error: ListPrice not initialized
Part part = new
{
    PartNumber = “1234-abcd”,
    Description = “Sample Part”
};
```

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Functional programming

- Honest method signatures
- Option data type

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Honest method signatures

- Failure throws exception
- Dishonest signature
- Principal of least surprise

```
// Int32 struct
public static int Parse(string s);

// success
var a = int.Parse("1");

// failure
var b = int.Parse("one");
```

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Option data type

Also known as *Maybe* (Haskell)

Union of two types:

- *None* – value is absent
- *Some* – value is present

Enforces checking of None/Some

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Building the option type

- Using value type
- No external access to underlying value

```
public struct Option<T>
{
    private readonly bool _hasValue;
    private readonly T _value;

    public TResult Match<TResult>(
        Func<TResult> none,
        Func<T, TResult> some)
    {
        return _hasValue ? some(_value) : none();
    }
}
```

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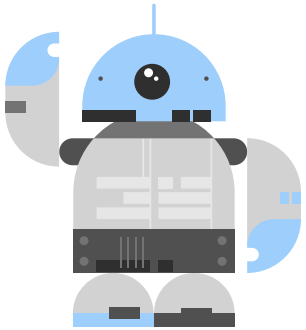
Building the none and some types



- Using value types
- No external access to underlying value

```
public struct None
{
    internal static readonly None Value = new();
}

public struct Some<T>
{
    internal Some(T value)
    {
        Value = value ?? throw new
            ArgumentNullException(nameof(value));
    }

    internal T Value { get; }
}
```

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Making it easy to use

- Code omitted for clarity
- Helper methods for None/Some syntax
- Implicit conversion of None, Some, value and reference types

```
public static class F
{
    public static None None => None.Value;

    public static Some<T> Some<T>(T value) =>
        new(value);
}

public struct Option<T>
{
    public static implicit operator
        Option<T>(None _) =>
            new();

    public static implicit operator
        Option<T>(Some<T> some) =>
            new(some.Value);

    public static implicit operator
        Option<T>(T value) =>
            value == null ? None : Some(value);
}
```

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null-worries/src/options

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A quick detour for a better view

```
public static class DictionaryExtensions
{
    public static Option<TValue>
        GetValue<TKey, TValue>(
            this IDictionary<TKey, TValue> source,
            TKey key) =>
                source.TryGetValue(key, out var value)
                    ? Some(value) : None;
}
```

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null-worries/src/options

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What have we got?

- ✓ Null worries?
- ✓ Explicit failure handling
- ✓ Success case handled
- ✓ Be happy!

```
var key = Guid.NewGuid().ToString();

Dictionary<string, string> dictionary =
    new() { { key, "Hello world!" } };

Console.WriteLine(
    dictionary.GetValue(key).Match(
        none: () => "Key not found",
        some: value => $"Value is \"{value}\"."));
```

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null-worries/src/builders

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Summary

- We use null when we do not have a better value to use
- It causes problems because others do not know what we mean by it
- We can do something about it by making our intentions clearer

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How do we make our intentions clearer?

- Default objects
- Ensuring valid object state
- Immutable objects and builders
- C# language features
- Functional programming

THANKYOU

QUESTIONS?

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