Hash Codes and Hashtables

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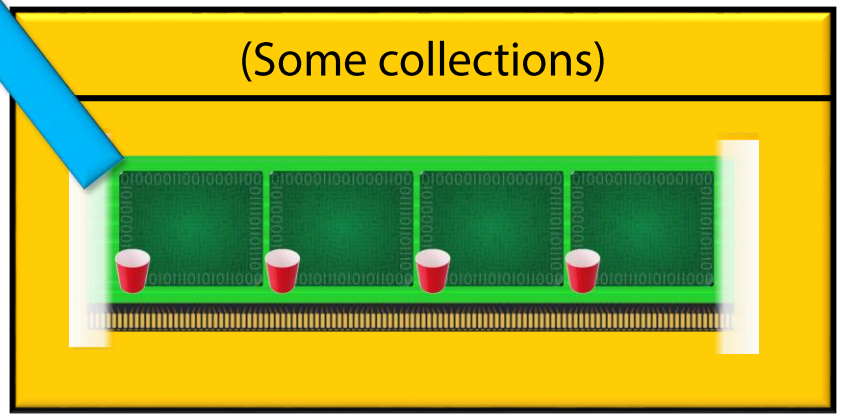
Hash codes enable collections with hash tables to work.
- Such as Dictionary<TKey, TValue>.
Requirements of a hashing function.
- Consistency with equality.
How to code up GetHashCode().
- Combine fields with XOR.
Exclusive OR.
- What it does.
- Why it's so good for hash codes.

How Hashtables Use Hash Codes

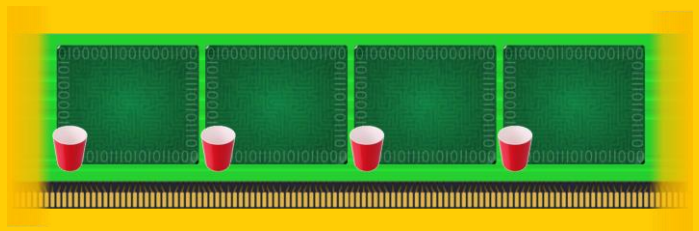
```
object.GetHashCode()
```



Required by hash tables

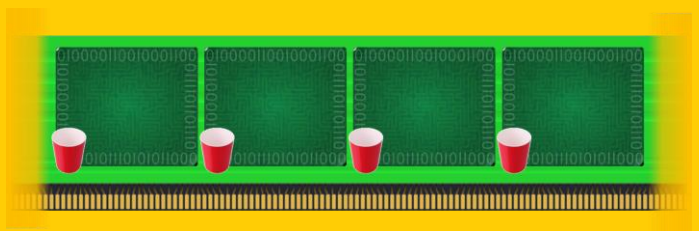
Collections with Hashtables

`Dictionary<TKey, TValue>`



(Hashtable of keys)

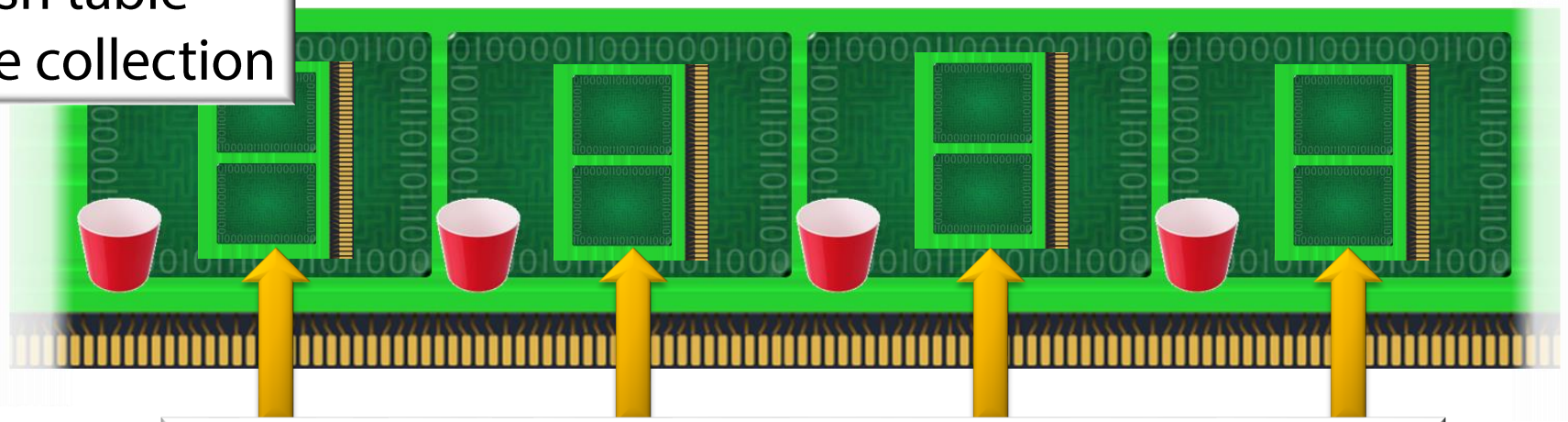
`HashSet<T>`



(Hashtable of values)

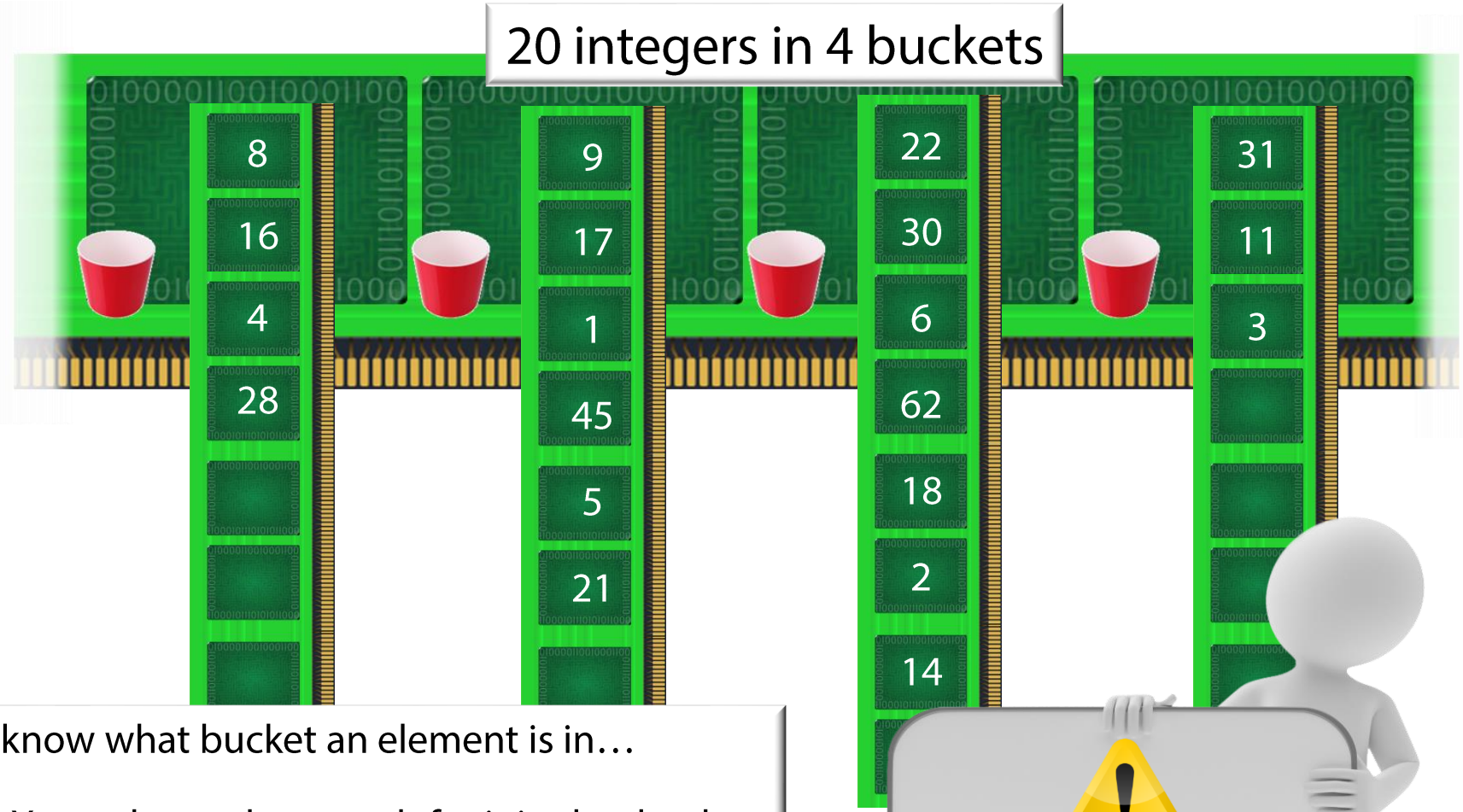
How Hashtables Work

Hash table
– large collection



Buckets (small collections)

How Hashtables Work



If you know what bucket an element is in…

…You only need to search for it in that bucket

…You can find it more quickly

Only works if elements are evenly spread

How Do You Choose a Bucket?

```
var x;
```

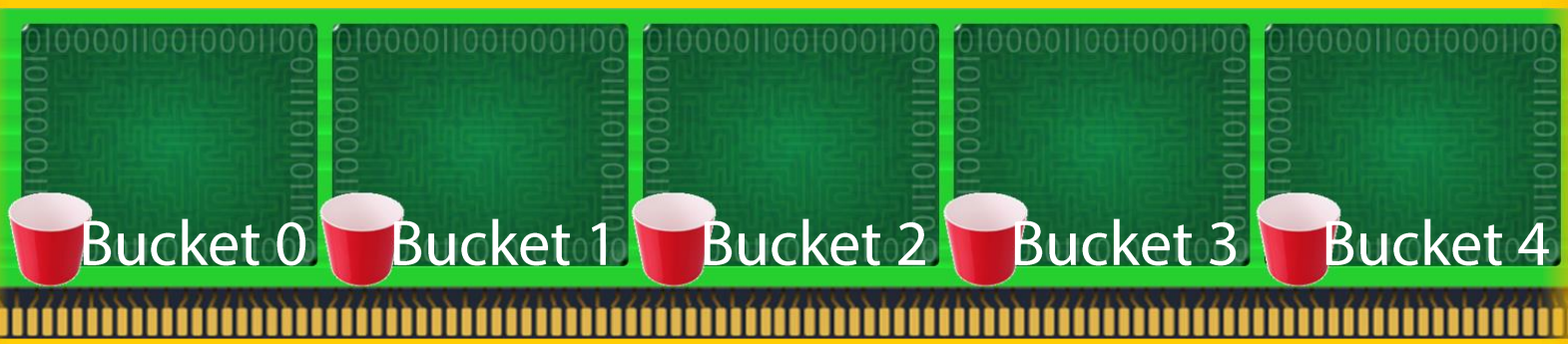
Value (can be any type) to go in hash table

```
int bucketIndex = x.GetHashCode() % nBuckets
```

This is the bucket the value should go in

Adding Strings to a HashSet

```
var myDict = new Dictionary<string, T>()
```



To add `"apple"`

```
"apple".GetHashCode()
```

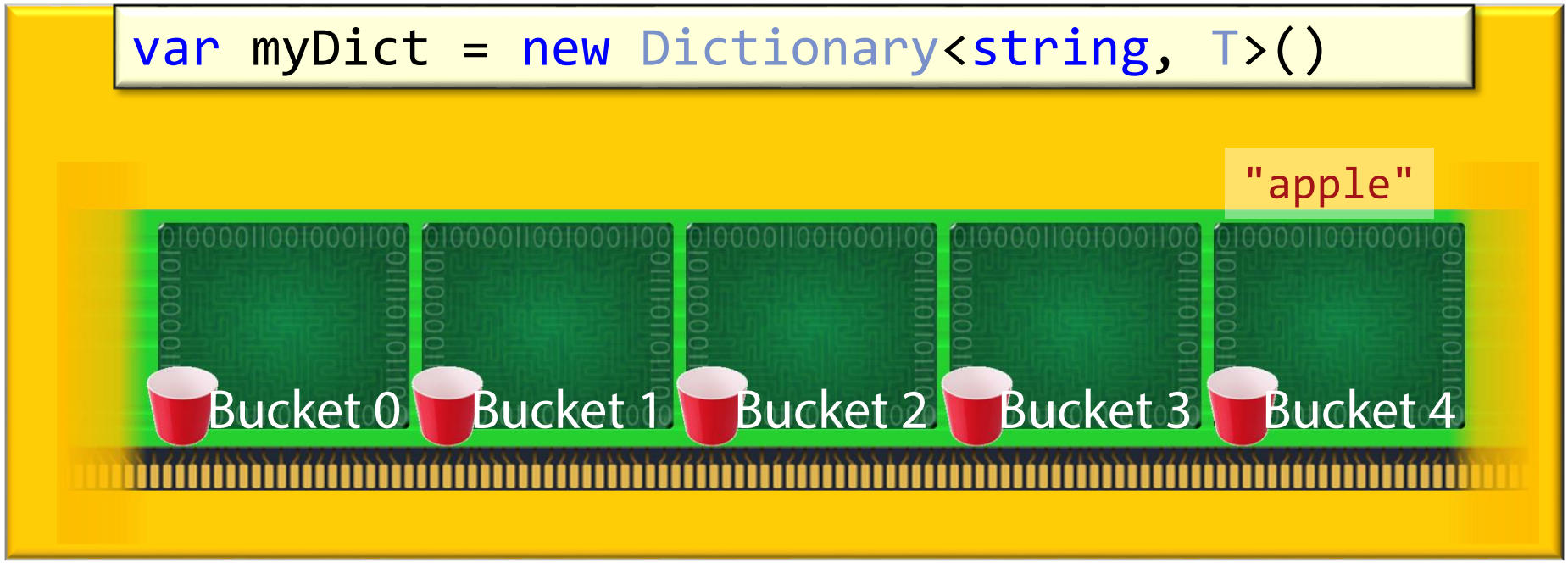
returns 1 657 858 284

```
"apple".GetHashCode() % 5
```

returns 4

Adding Strings to a HashSet

```
var myDict = new Dictionary<string, T>()
```



To add "pear"

```
"apple".GetHashCode()
```

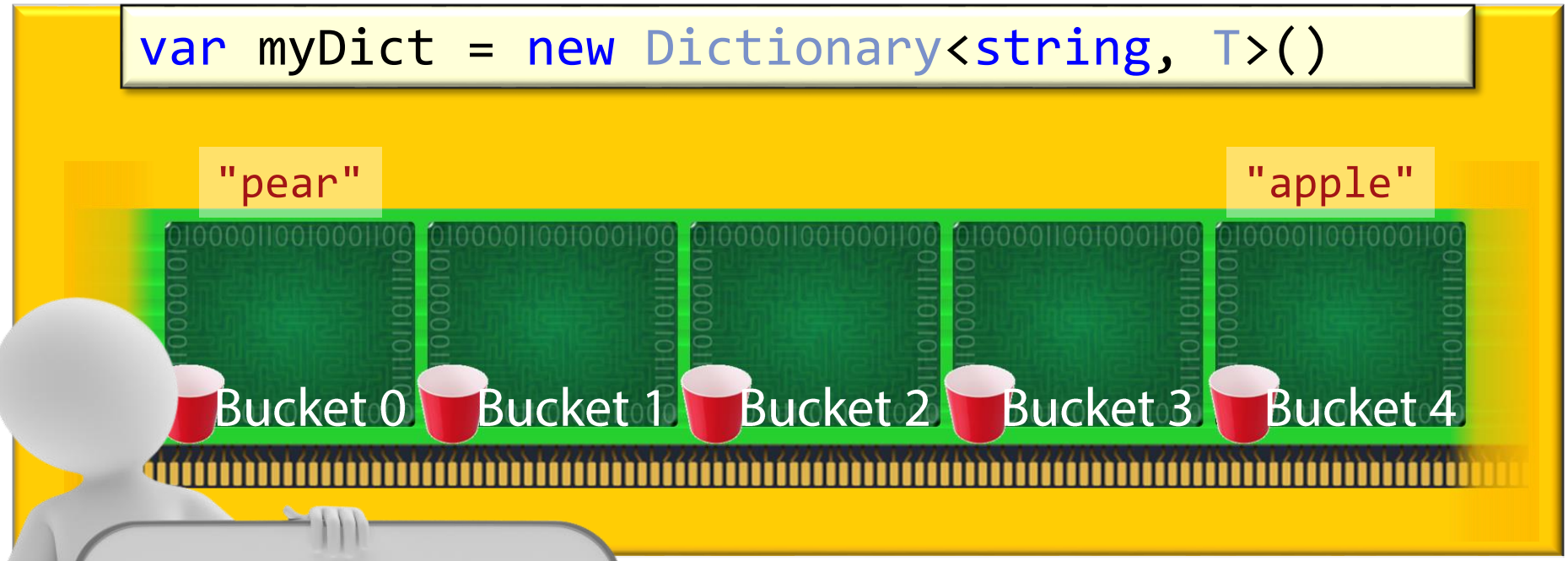
returns -422 187 275

```
"apple".GetHashCode() % 5
```

returns 0

Looking up Strings in a HashSet

```
var myDict = new Dictionary<string, T>()
```

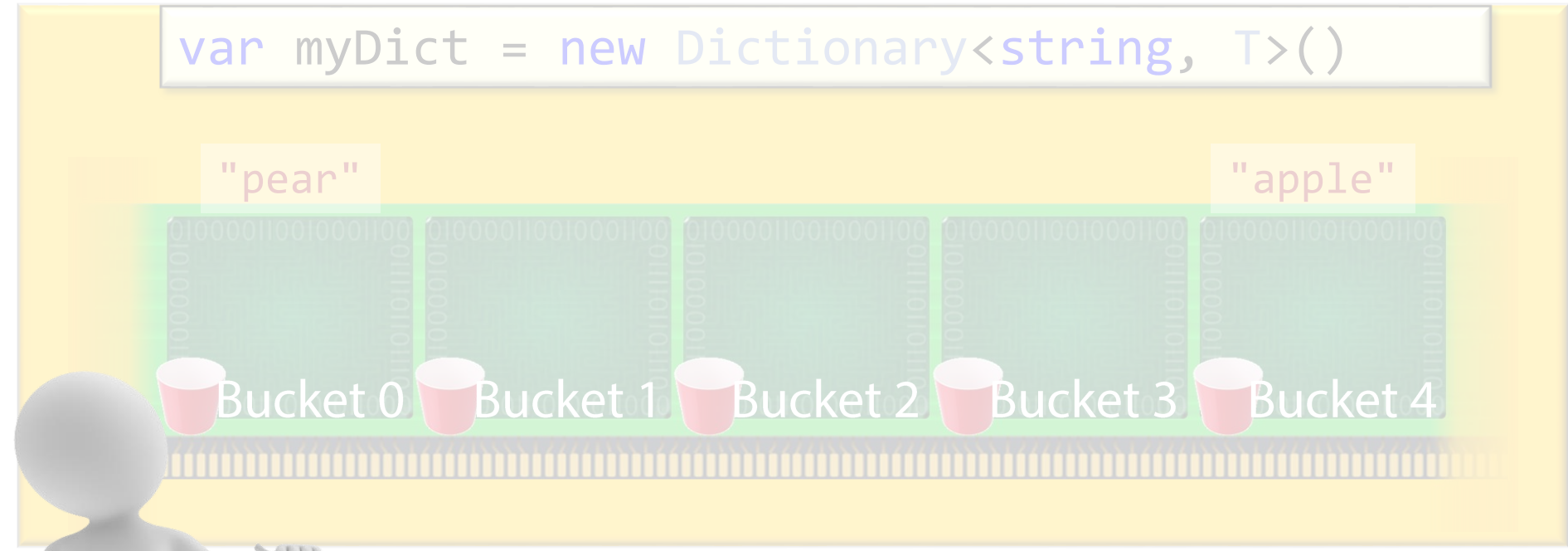


This is all for performance
so you don't need
to search many elements

```
Dict["apple"]
de()                    returns 1 657 858 284
de() % 5                returns 4
```

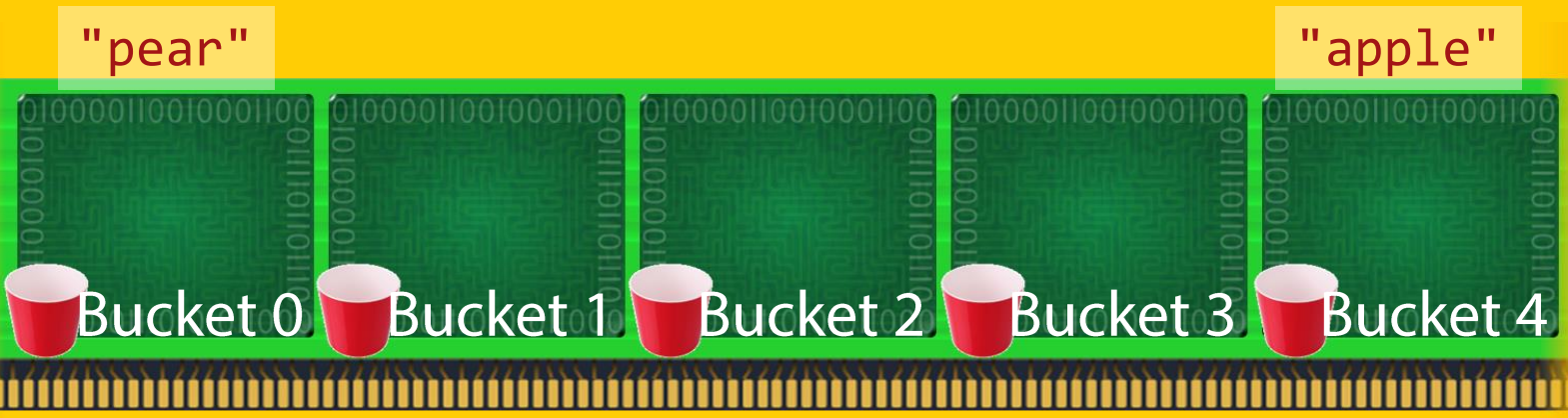
Hash Codes and Equality

```
var myDict = new Dictionary<string, T>()
```



Looking up a String

```
var myDict = new Dictionary<string, T>()
```




```
myDict["Apple"]
```

```
"Apple".GetHashCode()
```

returns 1 657 859 532

```
"Apple".GetHashCode() % 5
```

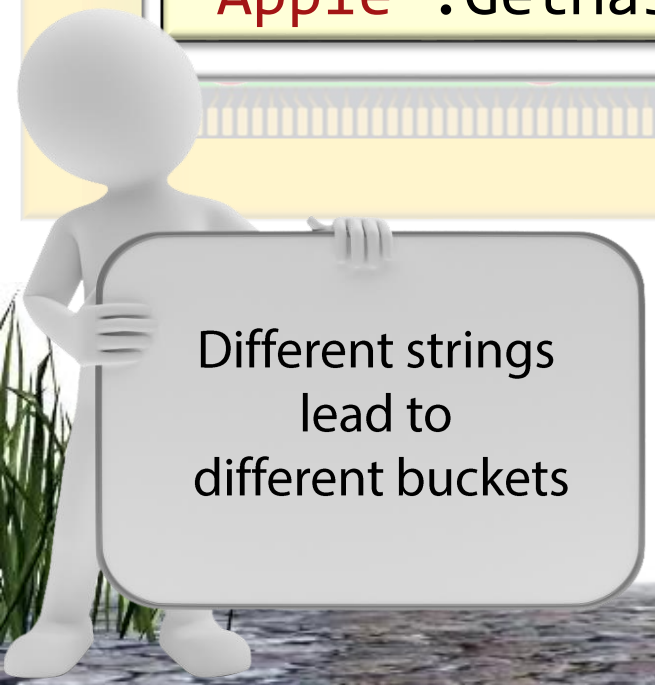
returns 2

Looking up a String

```
var myDict = new Dictionary<string, T>()
```

```
"apple".GetHashCode() % 5
```
leads to bucket 4

```
"Apple".GetHashCode() % 5
```
leads to bucket 2



Looking up a String

Suppose keys are case-insensitive:

```
var myDict = new Dictionary<string, string>
        (StringComparer.OrdinalIgnoreCase);
```

With this dictionary, if we look up "Apple"…

…we expect to match with "apple":

… This only works if…

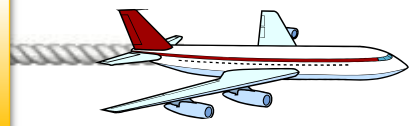
```
GetHashCode("apple") % 5
GetHashCode("Apple") % 5
```

leads to the same bucket

string.GetHashCode() won't do this
- so this dictionary can't use string.GetHashCode()

GetHashCode() Requirements

If two values x and y evaluate equal …
…then they **must** have the same hash code



```
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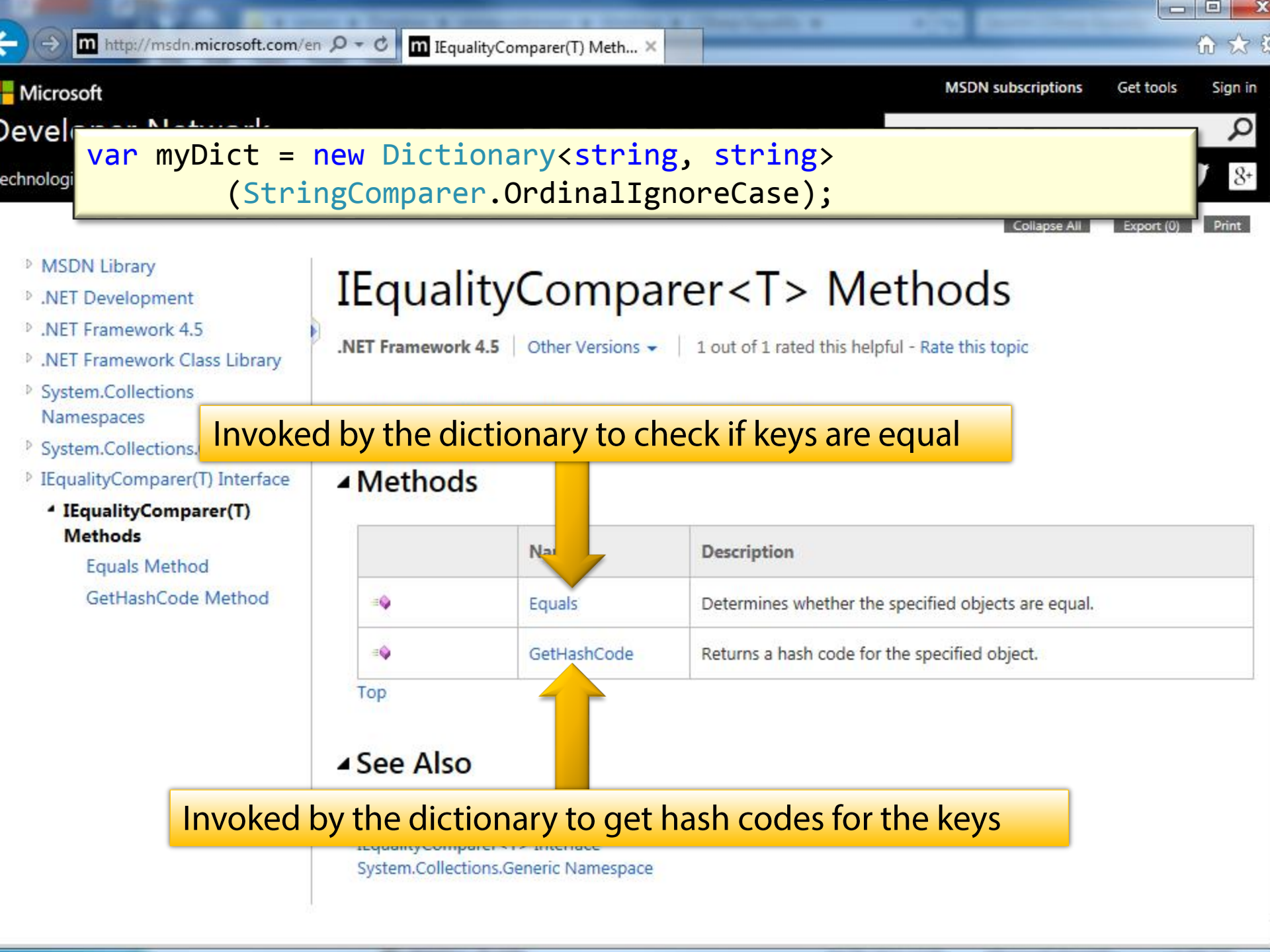

GetHashCode() Requirements

If two values x and y evaluate equal …
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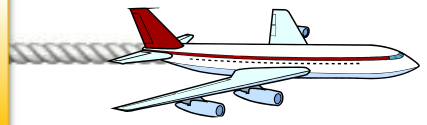
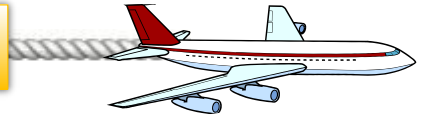


Hash codes must be quick to calculate

(Because dictionaries etc. invoke `GetHashCode()` frequently)

Hash codes are evenly spread across `int` values



(Because you want values to be evenly spread over the buckets)

What is Exclusive-OR (XOR)

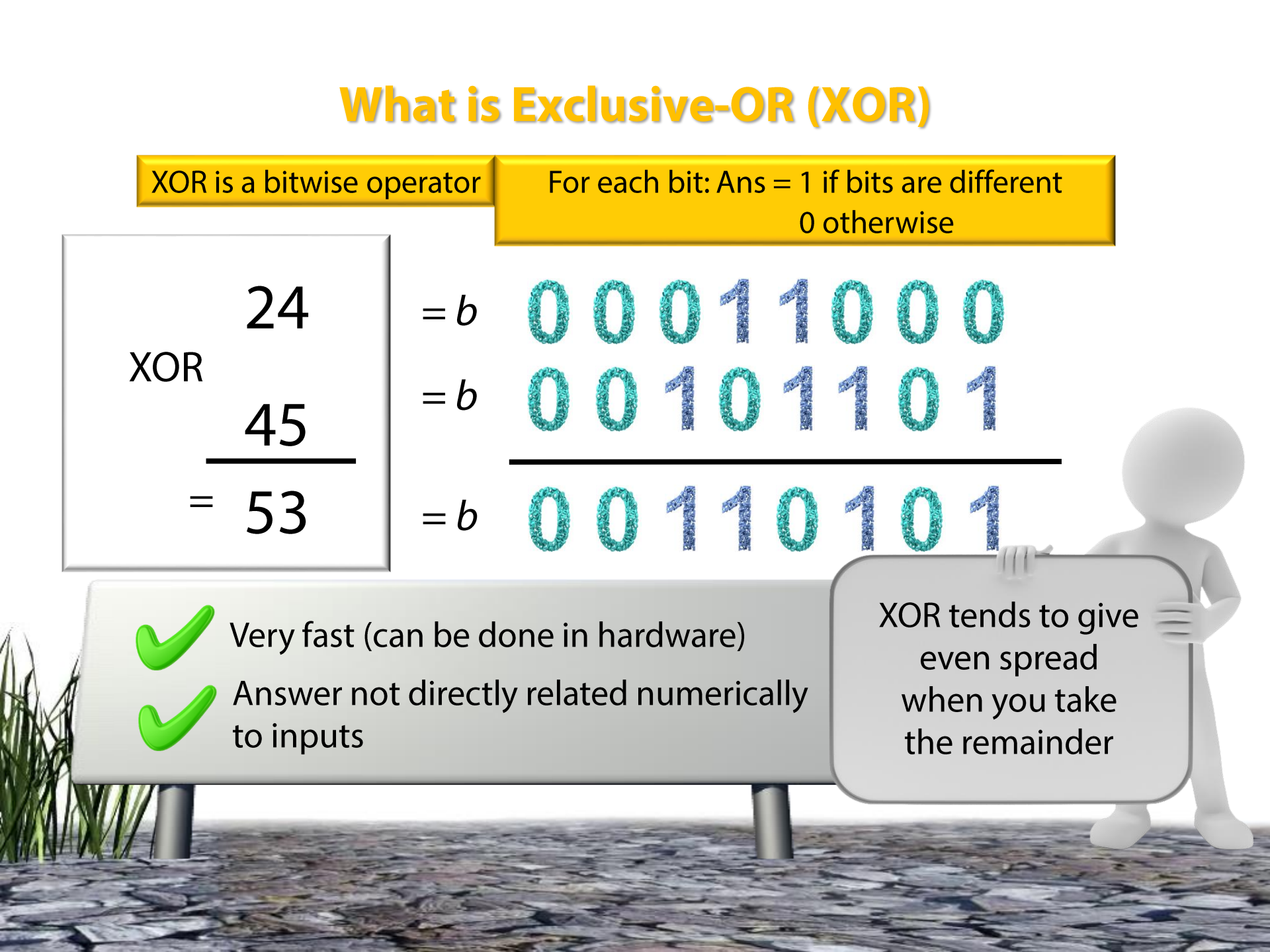
XOR is a bitwise operator

For each bit: Ans = 1 if bits are different
0 otherwise

	24	$= b$ 0 0 0 1 1 0 0 0
XOR	45	$= b$ 0 0 1 0 1 1 0 1
$=$	53	$= b$ 0 0 1 1 0 1 0 1

- ✓ Very fast (can be done in hardware)
- ✓ Answer not directly related numerically to inputs

XOR tends to give even spread when you take the remainder



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Duration: 5h 16m
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Released: 8/26/2013
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Hash Code Algorithms

Basic Procedure:

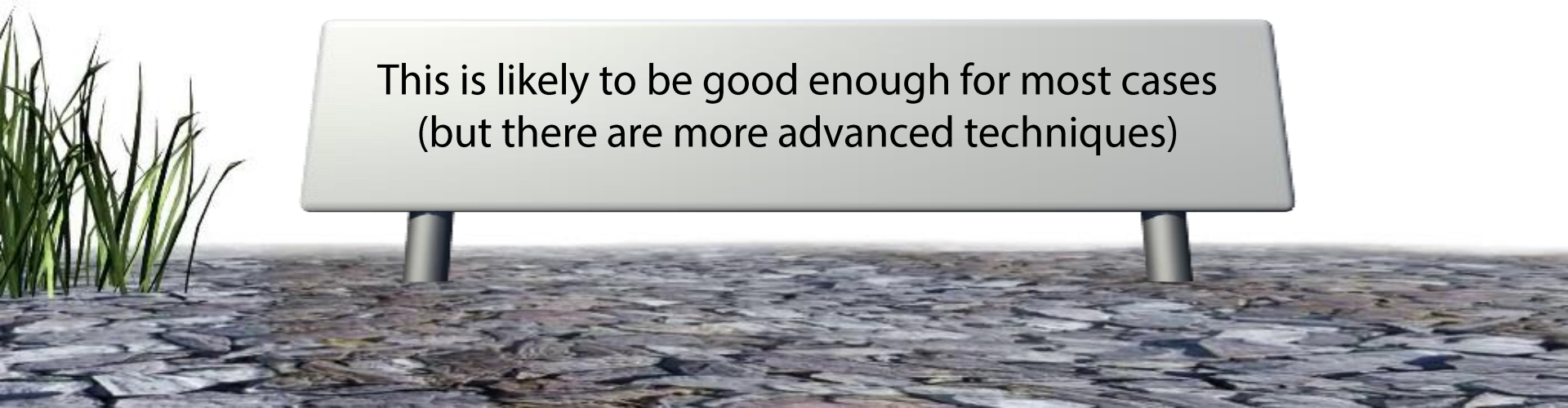
1. Take each field that's used to evaluate equality

   For each field…

   (i). Map any 'equal' values into the same value

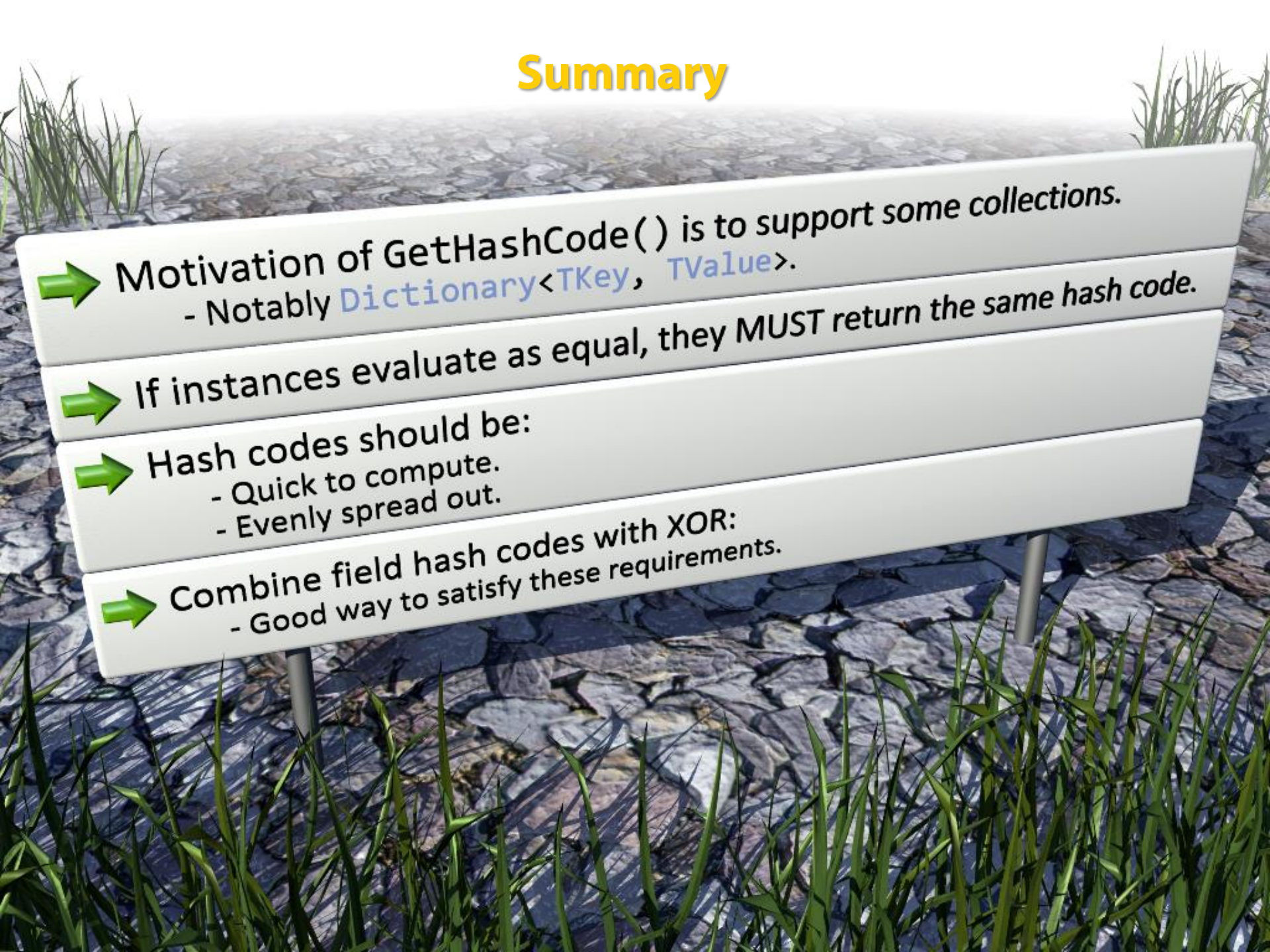
   (ii). Get the hash code of the mapped field value

2. XOR the invidual hash codes together



This is likely to be good enough for most cases
(but there are more advanced techniques)

Summary


Motivation of GetHashCode() is to support some collections.
- Notably Dictionary<TKey, TValue>.
If instances evaluate as equal, they MUST return the same hash code.
Hash codes should be:
- Quick to compute.
- Evenly spread out.
Combine field hash codes with XOR:
- Good way to satisfy these requirements.