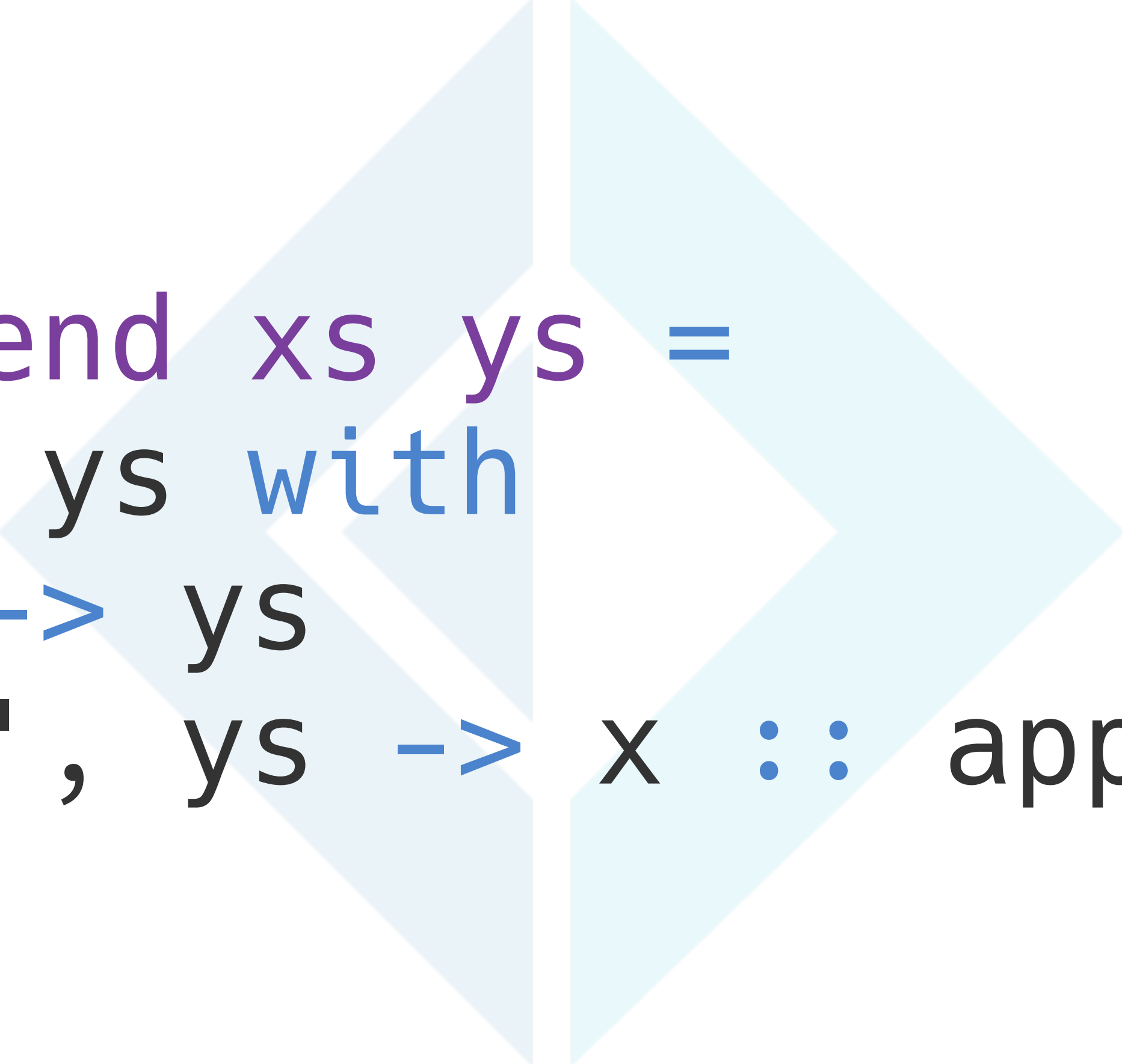




5 Levels of Testing

Mike Harris



```
let rec append xs ys =  
  match xs, ys with  
  | [], ys -> ys  
  | x :: xs', ys -> x :: append xs' ys
```

Manually test
the code



Level 1

Manual Testing

Example> **fsharp** **Tests.fs**

> **append** [] [1];;

val it : int list = [1]

> **append** [1] [];;

val it : int list = [1]

> **append** [1; 2] [3; 4];;

val it : int list = [1; 2; 3; 4]

Write hundreds of
unit & integration
tests for the code



Level 2

Automated Testing

[<Fact>]

```
let ``Given empty list with list it must return list`` () =  
    Assert.Equal<Collections.Generic.IEnumerable<int>>(  
        [1], append [] [1])
```

[<Fact>]

```
let ``Given list with empty list it must return list`` () =  
    Assert.Equal<Collections.Generic.IEnumerable<int>>(  
        [1], append [1] [])
```

[<Fact>]

```
let ``Given two list it must concat them`` () =  
    Assert.Equal<Collections.Generic.IEnumerable<int>>(  
        [1; 2; 3; 4], append [1; 2] [3; 4])
```

Model the code
and automatically
generate exhaustive
tests for every possible
permutation of the code



Level 3

Property Testing

[<Property>]

```
let ``Append with empty returns list``  
  (xs : int list) =  
    xs = append [] xs  
    && xs = append xs []
```

[<Property>]

```
let ``Append will be length of both``  
  (xs : int list, ys : int list) =  
    List.length xs + List.length ys =  
      (append xs ys |> List.length)
```

[<Property>]

```
let ``Append will contain members``  
  (x : int, ys : int list) =  
    append [x] ys |> List.contains x
```


Formally prove that
it is mathematically
impossible for the
code to have bugs



Level 4

Proof

append : **Vect** n a -> **Vect** m a -> **Vect** (m + n) a

append [] ys ?= ys

append (x :: xs) ys ?= x :: append xs ys

```
simple.append_lemma_2 = proof {  
  intros;  
  compute;  
  rewrite (plusSuccRightSucc m len);  
  trivial;  
}
```

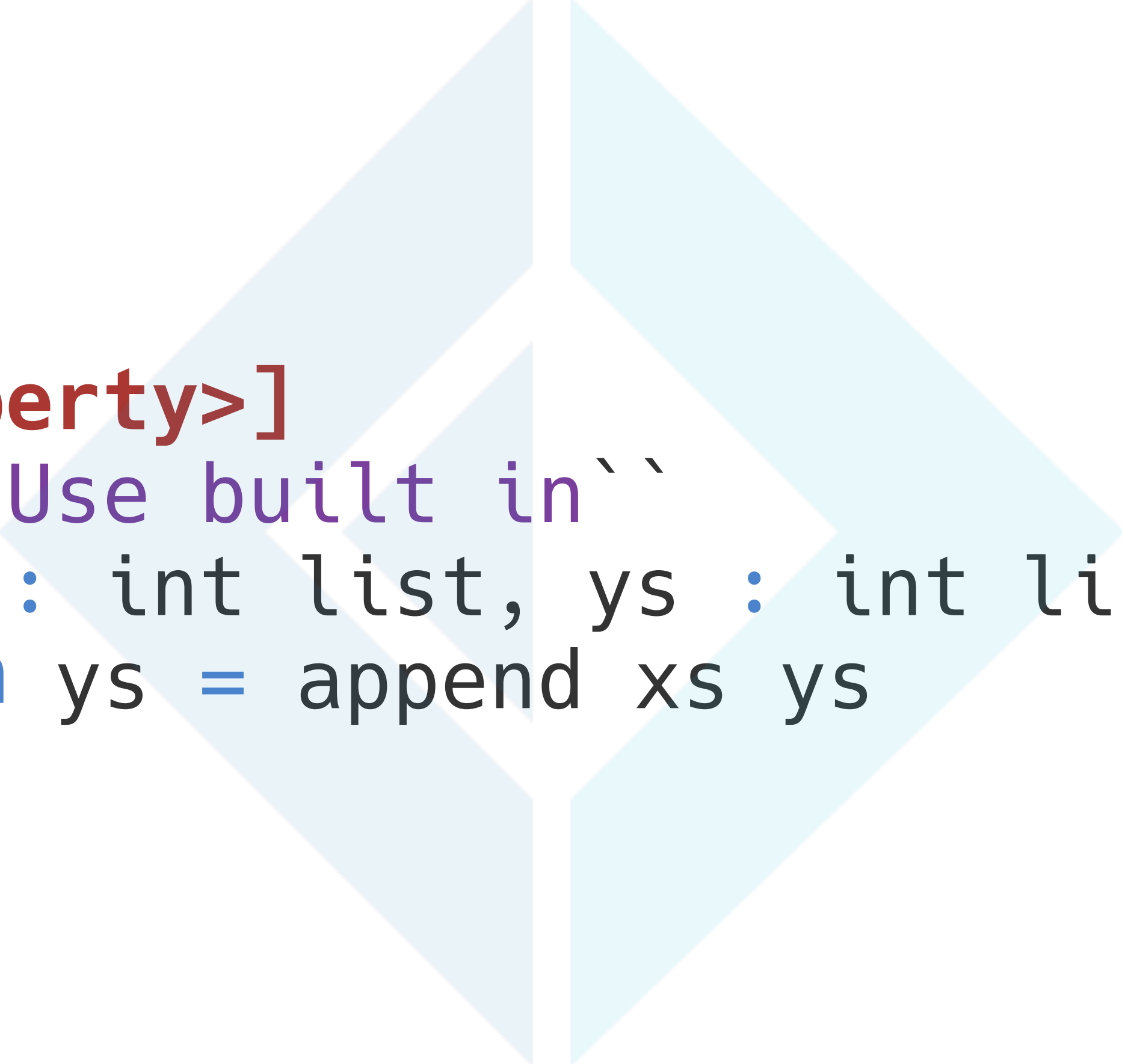
```
simple.append_lemma_1 = proof {  
  intros;  
  compute;  
  rewrite sym (plusZeroRightNeutral m);  
  exact value;  
}
```


Delete the code



Level 5

Delete the Code



```
[<Property>]
let ``Use built in``
  (xs : int list, ys : int list) =
    xs @ ys = append xs ys
```



```
let rec append xs ys =  
match xs, ys with  
| [], ys -> ys  
| x :: xs', ys -> x :: append xs' ys
```

`xs @ ys`

Manually test
the code



Write hundreds of
unit & integration
tests for the code



Model the code
and automatically
generate exhaustive
tests for every possible
permutation of the code



Formally prove that
it is mathematically
impossible for the
code to have bugs



Delete the code



Less Obvious

```
var total = 0.0;
foreach (var order in orders)
{
    if (order.Zip == 53202)
        total += order.Price * order.Quantity;
}
```



```
var total = 0.0;  
foreach (var order in orders)  
{  
    if (order.Zip == 53202)  
        total += order.Price * order.Quantity;  
}
```

```
var total = orders  
    .Where(order => order.Zip == 53202)  
    .Select(order => order.Price * order.Quantity)  
    .Aggregate(0.0, (sub, amount) => sub + amount);
```

Take Aways

- Learn the frameworks you have available.
- Learn about different kinds of abstractions.
- Look for tools that already solve the problems you have.



Thank you

Mike Harris

5 Levels of Testing
<https://bit.ly/2sojN0b>

@MikeMKH



Source

- [C# code] <https://github.com/MikeMKH/talks/blob/master/say-goodbye-to-the-for-loop-with-higher-order-functions/csharp/test/Example.cs>
- [F# logo] <https://fsharp.org/img/logo/fsharp512.png>
- [F# code] <https://github.com/MikeMKH/talks/blob/master/5-levels-of-testing/Example/Tests.fs>
- [Idris logo] <https://github.com/idris-lang/Idris-dev/blob/master/icons/text-x-idris.svg>
- [Idris code] <https://github.com/idris-lang/Idris-dev/blob/61cf812e97c0cf07a9596c1d36ab5a70eb5758b2/test/proof001/test029.idr#L21-L41>
- [Meme] <https://twitter.com/DavidKPiano/status/988479847352750080>