Syntax Matters:
Writing abstract computations in F#

Tomas Petricek
University of Cambridge

Don Syme
Microsoft Research

Non-standard computations
in various languages and F#

C# 5.0 asynchronous methods

```
async Task<string> GetLength(string url) {
   var html = await DownloadAsync(url);
   return html.Length;
}
```

```
getLength : string → Async<int>

let getLength url = async {
   let! html  = downloadAsync url
   return html.Length  }
```

Python generators

```
def duplicate(inputs):
    for number in inputs:
        yield number
        yield number * 10
```

```
duplicate : seq<int> → seq<int>

let duplicate inputs = seq {
    for number in inputs do
        yield number
        yield number * 10 }
```

Not just a monad!

Unifying single-purpose syntax with F# computation expressions

F# computation expressions

Unify single-purpose extensions

- Custom binding
- Custom returning or yielding
- Custom loops and exceptions

Computation expression principles

- Unify single-purpose syntax
- Reuse standard syntax of F#
- Allow flexible custom interpretation

What types of computations?

Library author decides

- Adding operations enables constructs
- Flexible types of operations

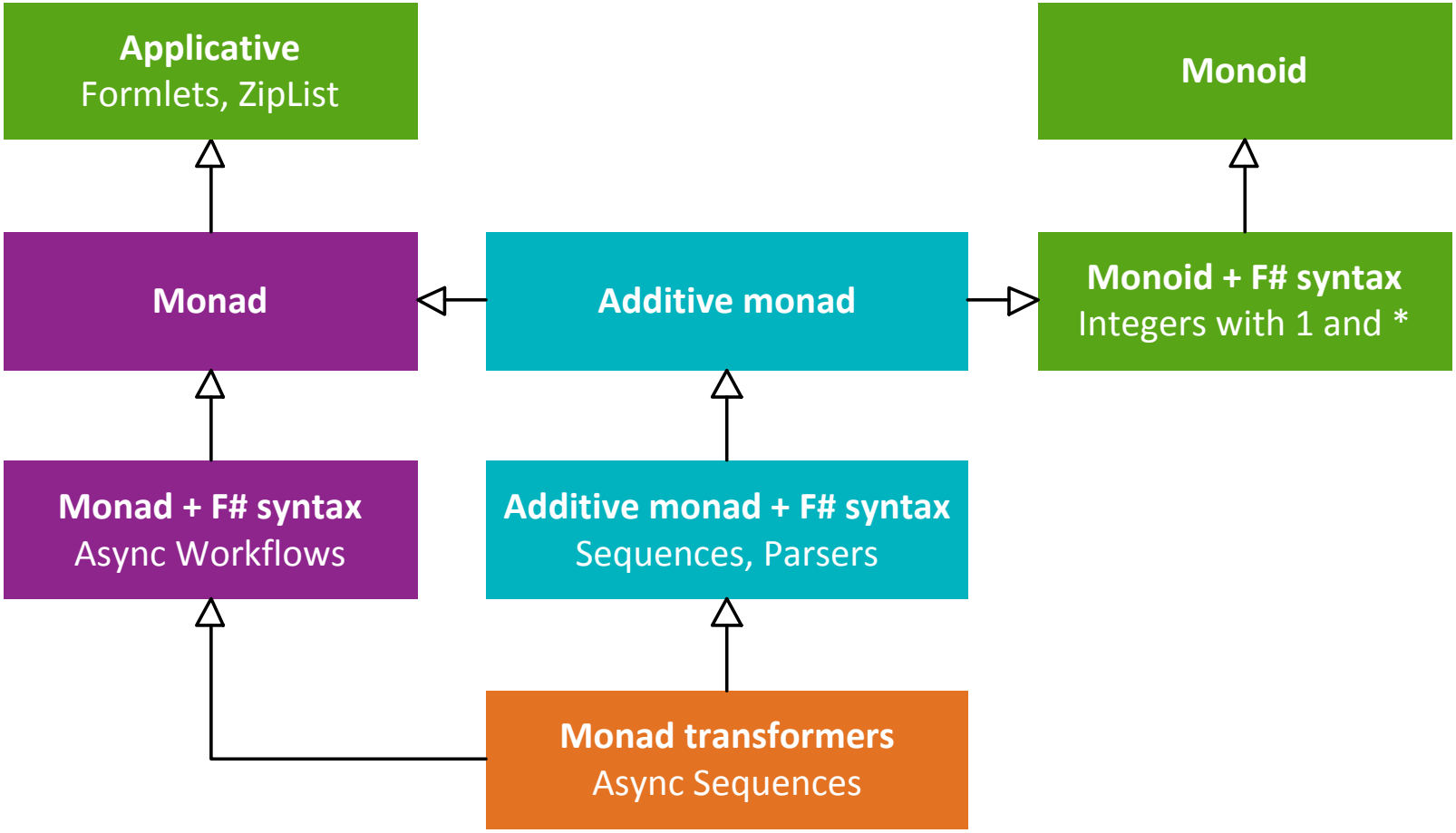
Enable custom for loops

for : [α] → (α → Mnd β) → Mnd β
for : Seq α → (α → Mnd β) → Mnd β

Paper identifies common abstractions

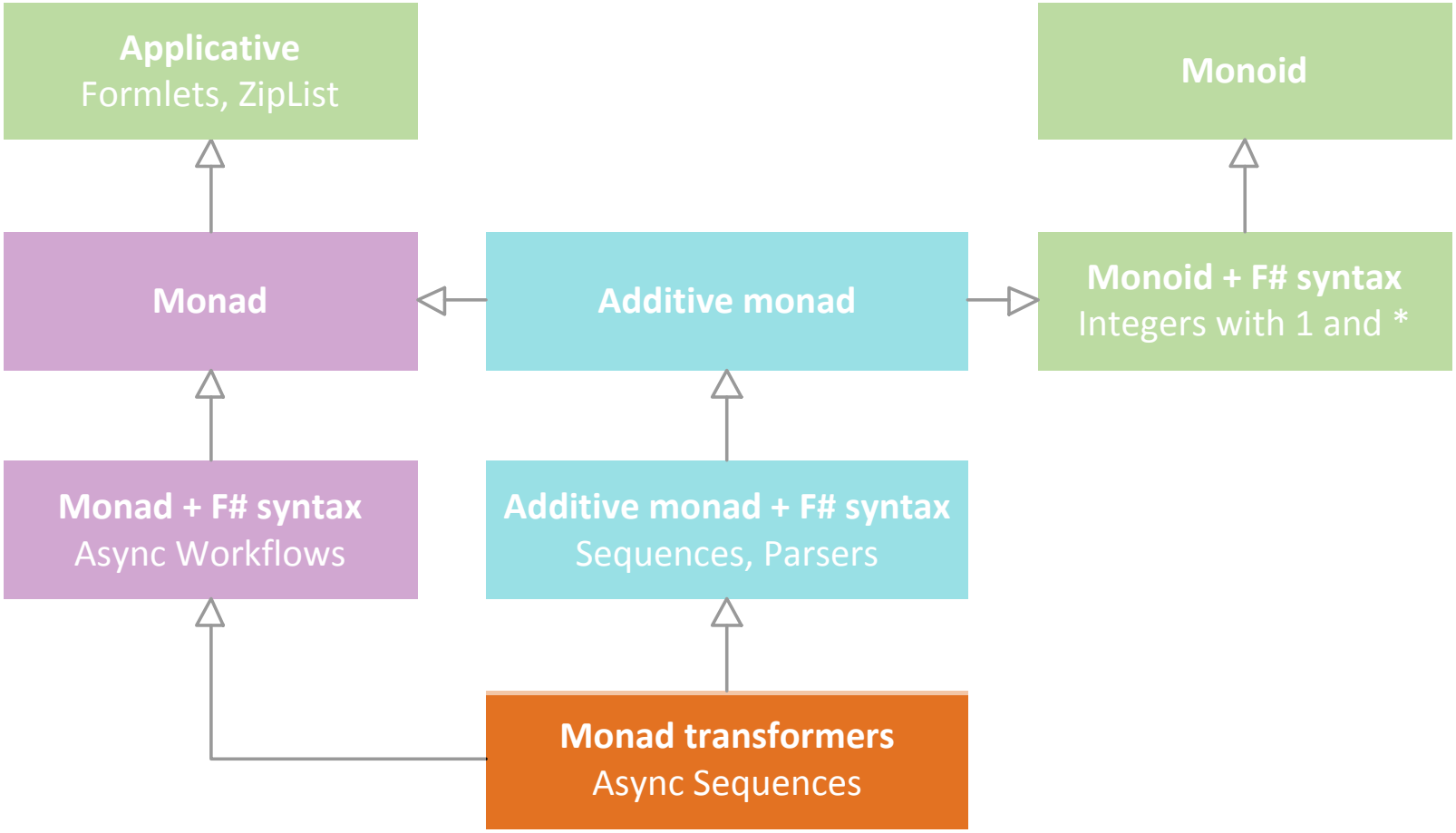
- Finds the most intuitive syntax

What can we express?



Common computation types
and syntax for them

What can we express?



Asynchronous and sequences

List transformer applied to async monad

```
let pages = asyncSeq {
    for url in addressStream do
        let! html = wc.AsyncDownload(url)
        yield url, html }
```

normal bind

lifted bind

```
for  : AsyncSeq α → (α → AsyncSeq β) → AsyncSeq β
bind : Async α    → (α → AsyncSeq β) → AsyncSeq β
for  : [α]        → (α → AsyncSeq β) → AsyncSeq β
```

Summary

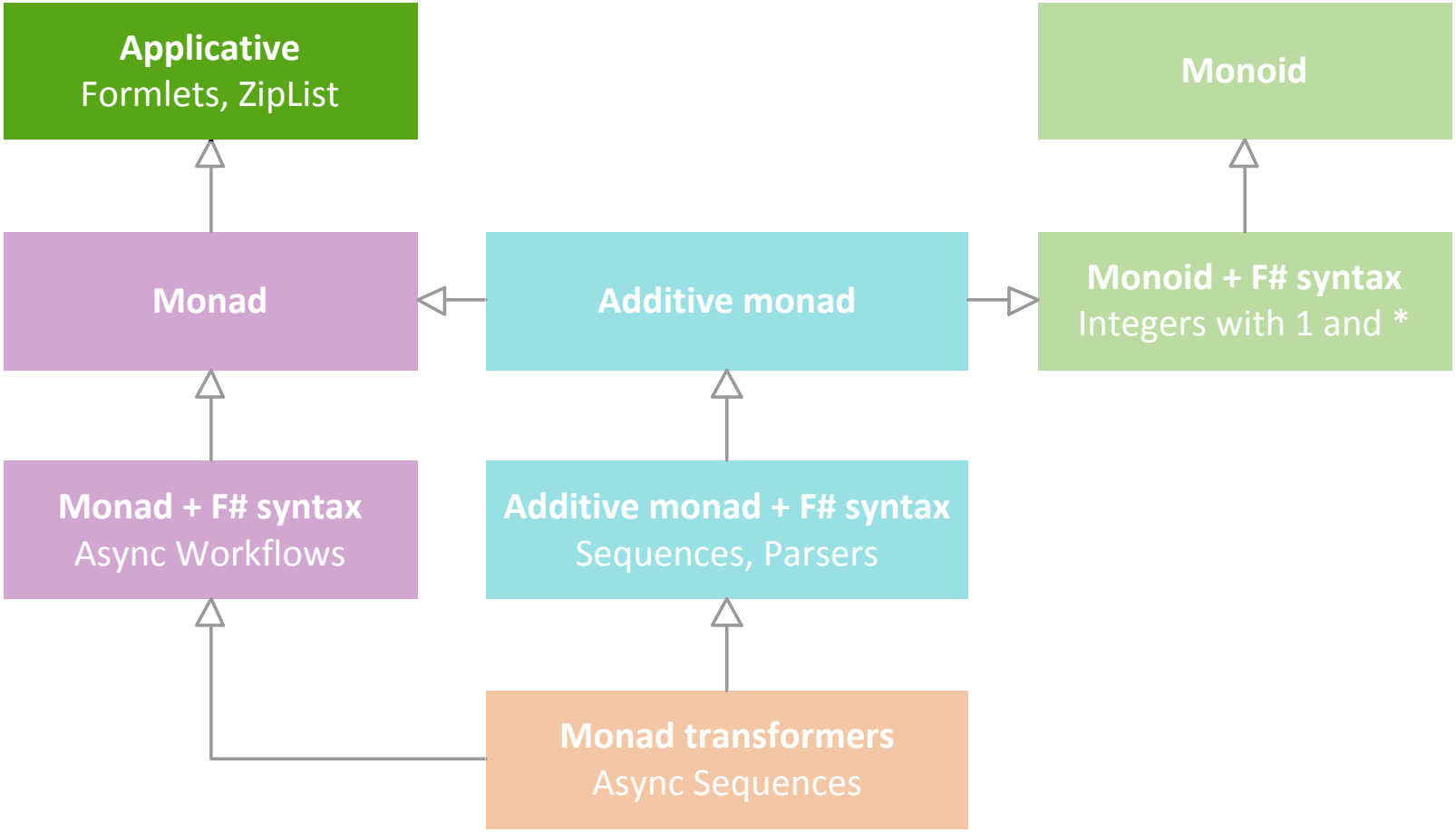
Syntax matters!

- Reinterpretation of standard syntax
- Better intuition than combinators

Flexibility is good!

- Wide range of computations
- Intuitive syntax for a computation

What can we express?



Applicative formlets

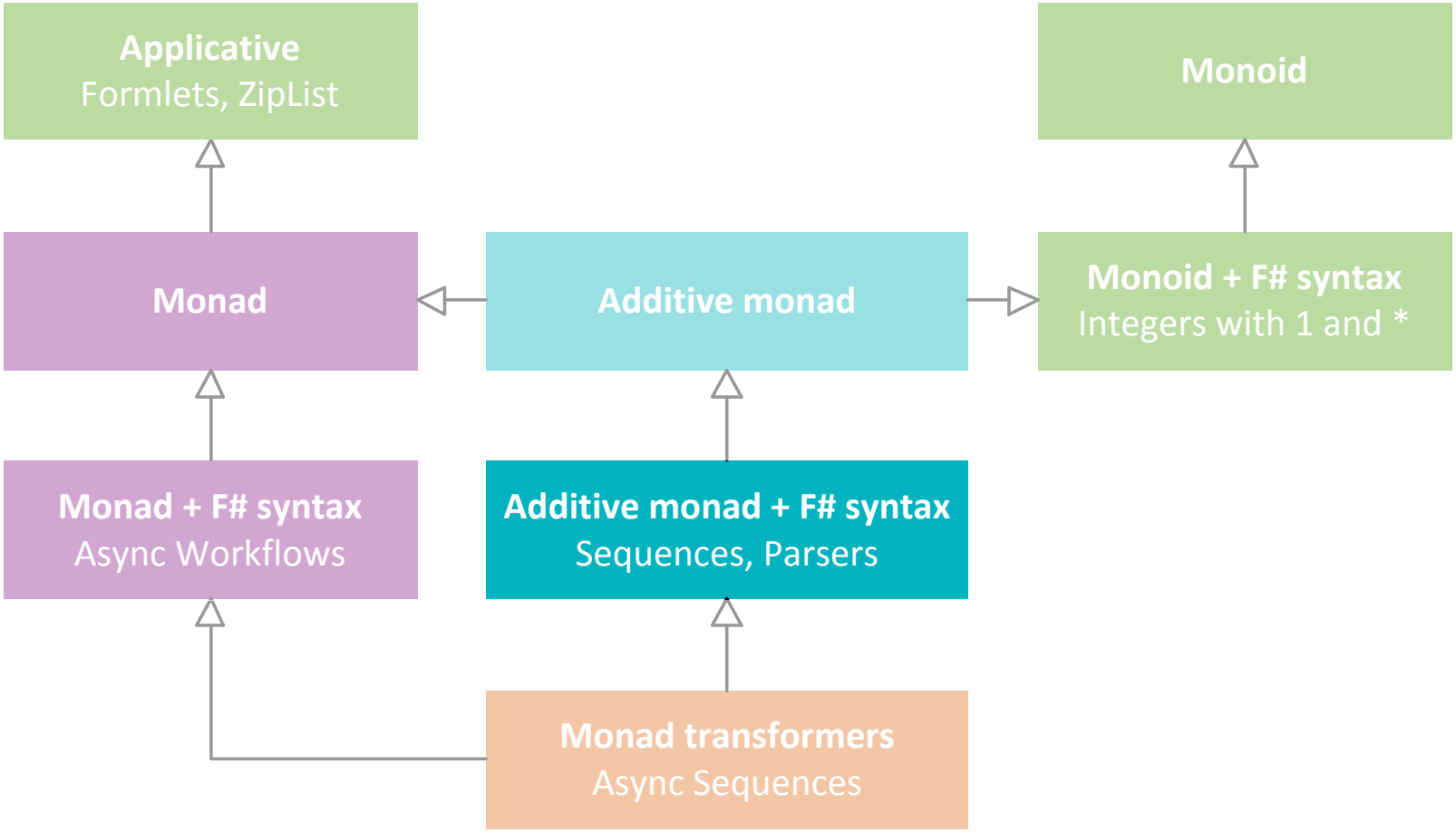
Generalization of monad

Computation structure cannot depend on values

```
let userFormlet = formlet {
  let! name = Formlet.textBox
  and gender = Formlet.dropDown ["Male"; "Female"]
  return name + " " + gender }
```

```
map    : Formlet α → (α → β) → Formlet β
merge  : Formlet α → Formlet β → Formlet (α × β)
return : α → Formlet α
```

What can we express?



Additive monad for sequences

Combines monad and monoid

- Uses **for** for monadic binding

```
seq {  yield! Directory.GetFiles(dir)
       for subdir in Directory.GetDirectories(dir) do
         yield! listFiles subdir }
```

```
for       : Seq α  → (α → Seq β) → Seq β
combine   : Seq α → Seq α → Seq α
yield     : α → Seq α
```

Additive monad for parsers

Combines monad and monoid

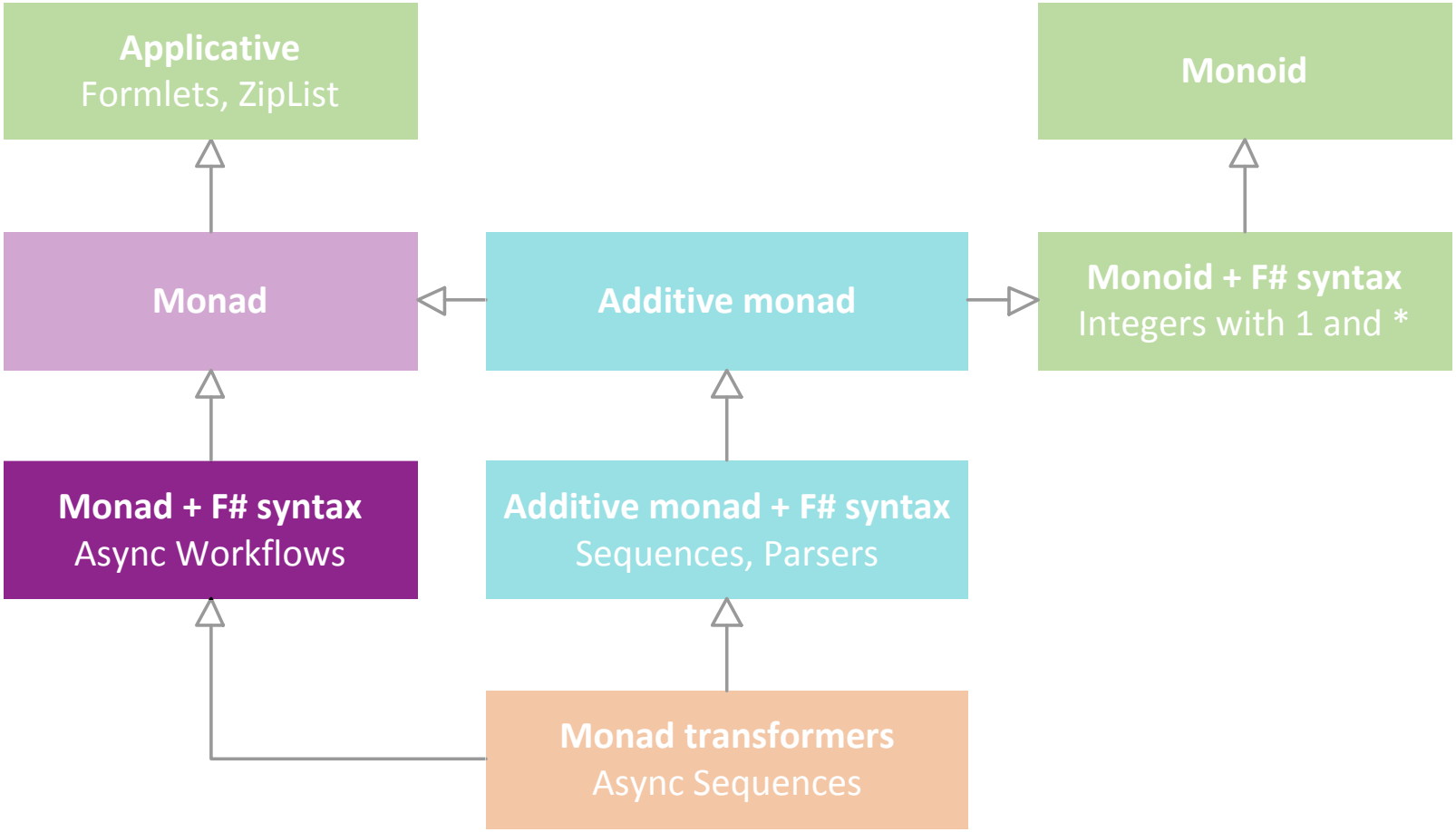
- Uses **let!** for monadic binding

```
let rec some p = parse {
  let! x = p
  let! xs = many p
  return x::xs }
```

```
and many p = parse {
  return! some p
  return [] }
```

```
bind     : Seq α  → (α → Seq β) → Seq β
combine  : Seq α → Seq α → Seq α
return   : α → Seq α
```

What can we express?



Monadic async workflows

Monad with standard F# control flow

```
async {
   while true do
      for color in [green; orange; red] do
         do! Async.Sleep(1000)
         displayLight color }
```

```
bind  : Async α → (α → Async β) → Async β
for   : [α]     → (α → Async 1) → Async 1
while : (1 → bool) → Async 1 → Async 1
```