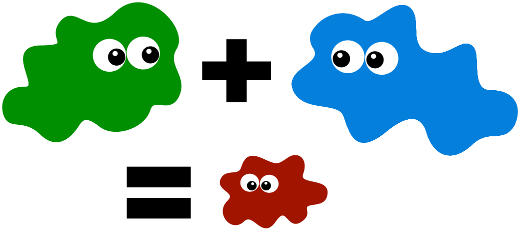
The Evolution of Curry

From Protozoon to Mammal

From Prolog to Haskell

The Best Genes of Both Parents



- functional (algebraic data types, higher order, laziness)
- logic (non-determinism, narrowing)

Why do You need Non-Determinism / Narrowing?

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- logic puzzles (wolf, sheep and cabbage)

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- ~~logic puzzles (wolf, sheep and cabbage)~~
- enumeration of test cases (SmallCheck)
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- circuit analysis (Wired)

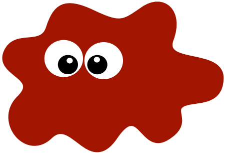
Why do You need Non-Determinism / Narrowing?

- ~~logic puzzles (wolf, sheep and cabbage)~~
- enumeration of test cases (SmallCheck)
- efficient enumeration of test cases (Lazy SmallCheck)
- circuit analysis (Wired)
- <insert your idea here>

The first of its Kind

characteristics PAKCS

- Portland Aachen Kiel Curry System
- Michael Hanus
- non-determinism, narrowing
- target language: Prolog
- search strategy: depth first



Non-Determinism

- overlapping rules induce non-determinism

```
coin :: Int
coin = 0
coin = 1
```

Non-Determinism

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```
coin :: Int
coin = 0
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Main> coin
```

Non-Determinism

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coin :: Int
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Main> coin
0
More?
```

Non-Determinism

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Main> coin
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More?
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Non-Determinism

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coin :: Int
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Main> coin
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More?
1
More?
No more Solutions
```

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coin :: Int
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Main> coin
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More?
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```
(?) :: a -> a -> a
x ? _ = x
_ ? y = y
```

Non-Determinism

- overlapping rules induce non-determinism

```
coin :: Int
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Main> coin
0
More?
1
More?
No more Solutions
```

```
(?) :: a -> a -> a
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_ ? y = y

coin’ :: Int
coin’ = 0 ? 1
```
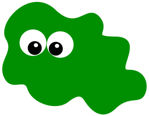

Functional Species

```
double :: Int -> Int
double x = x+x
```

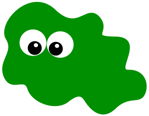


call-by-value

call-by-name

call-by-need

Functional Species



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call-by-value

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double (0+1) = double 1
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call-by-name

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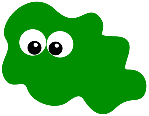
Functional Species



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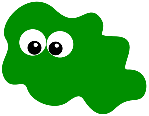

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double :: Int -> Int
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call-by-value

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double (0+1) = double 1
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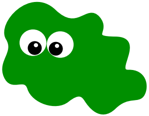
Functional Species



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call-by-name

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double (0+1) = (0+1) + (0+1)
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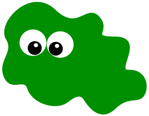
call-by-need

Functional Species



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call-by-need

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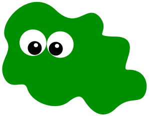

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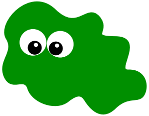

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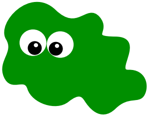

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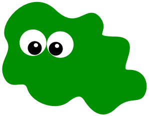

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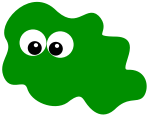

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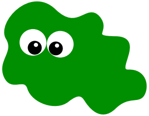
Functional Species



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```

Functional Logic Species

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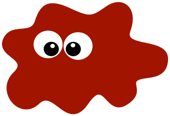

call-by-value

call-by-name

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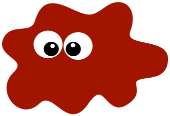
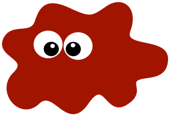


call-by-value

```
double coin = double (0|1)
```

call-by-name

Functional Logic Species



```
coin :: Int
coin = 0
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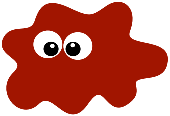
```

call-by-value

```
double coin = double (0|1)
            = double 0 | double 1
```

call-by-name

Functional Logic Species



```
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call-by-value

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```

call-by-name

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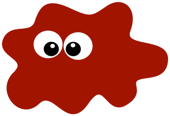

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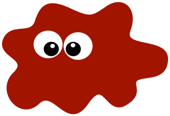
Functional Logic Species



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call-by-value

```
double coin = double (0|1)
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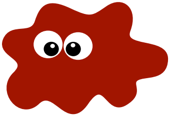
```

$\Longrightarrow$ call-time choice

call-by-name

Functional Logic Species



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call-by-value

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double coin = double (0|1)
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```
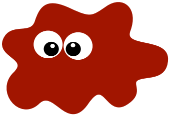

⟹ call-time choice

call-by-name

```
double coin = coin+coin
```

Functional Logic Species



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coin :: Int
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call-by-value

```
double coin = double (0|1)
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            = 0+0 | 1+1
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```
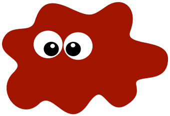

$\Longrightarrow$ call-time choice

call-by-name

```
double coin = coin+coin
            = (0|1)+(0|1)
```

Functional Logic Species



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double coin = double (0|1)
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            = 0+0 | 1+1
            = 0 | 2
```

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call-by-name

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double coin = coin+coin
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```
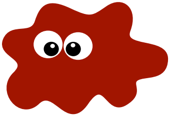

Functional Logic Species



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call-by-value

```
double coin = double (0|1)
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            = 0 | 2
```

$\Longrightarrow$ call-time choice

call-by-name

```
double coin = coin+coin
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```

$\Longrightarrow$ run-time choice

Functional Logic Species

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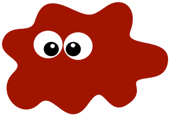
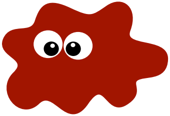


call-by-need

Functional Logic Species



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coin :: Int
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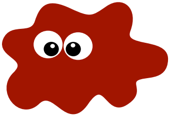
call-by-need

```
double coin = let x=coin in x+x
```

Functional Logic Species



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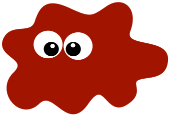
Functional Logic Species



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call-by-need

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double coin = let x=coin in x+x
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```

Functional Logic Species

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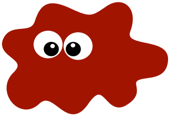

call-by-need

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double coin = let x=coin in x+x
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```

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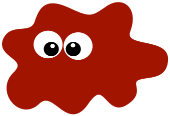

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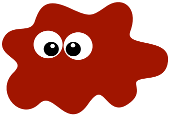
$\Longrightarrow$ run-time choice

Functional Logic Species



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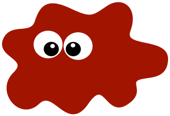
Functional Logic Species



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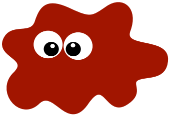

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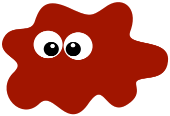
Functional Logic Species



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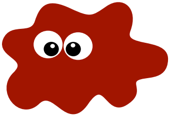

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Non-Determinism

```
insertnd :: a -> [a] -> [a]
insertnd x ys = x:ys
insertnd x (y:ys) = y:insertnd x ys
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Main> insertnd 3 [1,2]
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Main> insertnd 3 [1,2]
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Non-Determinism

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sort :: [a] -> [a]
sort xs | ordered ys = ys
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Narrowing

```
list :: [Int]
list = ys ++ [1]
 where
  ys free
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Main> list
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Main> list
[1]
[_a,1]
```

Narrowing

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Main> list
[1]
[_a,1]
[_a,_b,1]
```

Narrowing

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list :: [Int]
list = ys ++ [1]
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Main> list
[1]
[_a,1]
[_a,_b,1]
[_a,_b,_c,1]
```

Narrowing

```
last :: [a] -> a
last xs | ys ++ [y] =:= xs = y
 where
  ys, y free
```

Narrowing

```
last :: [a] -> a
last xs | ys ++ [y] == xs = y
 where
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```

Narrowing

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last :: [a] -> a
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Main> last [1..4]
```

Narrowing

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last :: [a] -> a
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```

Narrowing

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Main> last [error "_|_",2]
```

Narrowing

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Main> last [error "_|_",2]
ERROR: '_|_'
```

~~Narrowing~~ Non-Determinism

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```

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pList :: [Peano]
pList = []
pList = peano : pList
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last xs | ys ++ [y] == xs = y
 where
  ys = pList
  y = peano
```

An Evolution Step

characteristics KiCS

- Kiel Curry System
- Bernd Braßel, Frank Huch
- non-determinism
- target language: Haskell
- search strategy: arbitrary, explicit searchtree
- On a Tighter Integration of Functional and Logic Programming, APLAS 2007

Killer Application

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prop_Insert :: Peano -> [Peano] -> Bool
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⋮
```

Haskell ND vs. Curry ND

Haskell ND

```
data Peano = Zero | Succ Peano
data [a] = [] | a : [a]

{[], [Zero], [Zero,Succ Zero], [Succ Zero,Zero], ...}
```

Haskell ND vs. Curry ND

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data Peano = Zero | Succ {Peano}
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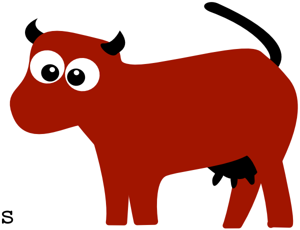
characteristics explicit-sharing

- library, available via hackage
- Sebastian Fischer, Oleg Kiselyov, Chung-chieh Shan
- non-determinism
- "target language": monadic Haskell
- search strategy: arbitrary, any `MonadPlus`
- Purely Functional Lazy Non-deterministic Programming, ICFP 2009



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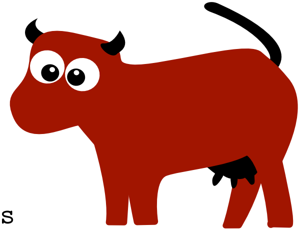

this is not the end of evolution!

Advertisement

Curry

The Flavor in Your Programming

PAKCS `www.informatik.uni-kiel.de/~pakcs`

KiCS `www.informatik.uni-kiel.de/prog/mitarbeiter/bernd-brassel/projects`

explicit sharing `sebfisch.github.com/explicit-sharing`

give it a try!

have fun!

have logical fun!