III. Funktionale Programmierung

- 1. Prinzipien der funktionalen Programmierung
- 2. Deklarationen
- 3. Ausdrücke
- 4. Muster (Patterns)
- 5. Typen und Datenstrukturen
- **6. Funktionale Programmiertechniken:** Funktionen höherer Ordnung

Funktionen höherer Ordnung: comp

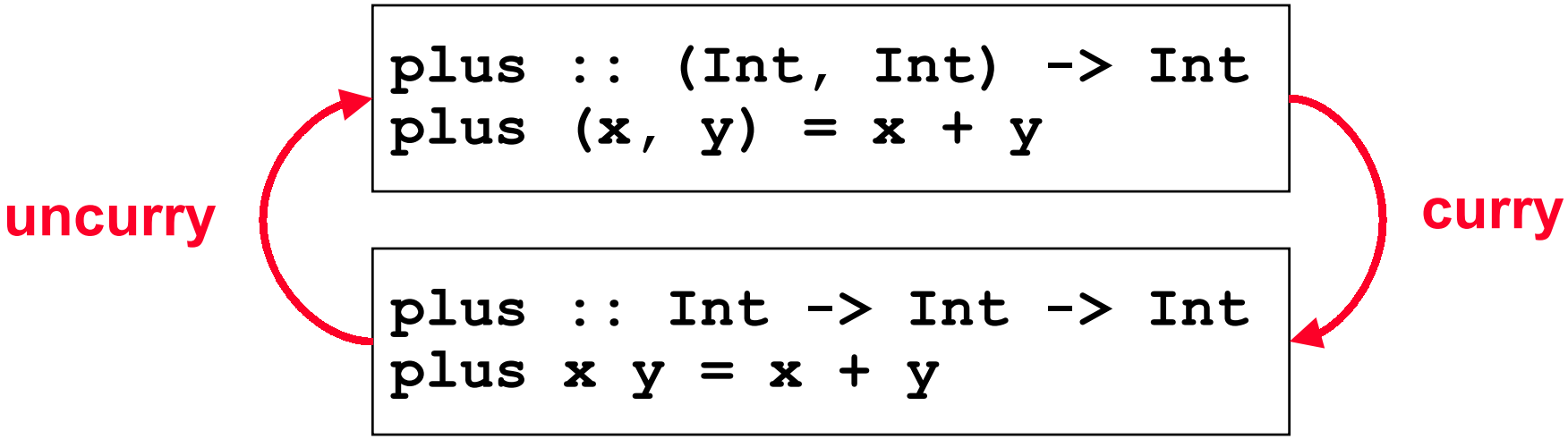
```
comp :: (b -> c) -> (a -> b) -> (a -> c)

comp f g = \x -> f (g x)
```

Argument vom Typ: `(b -> c)`

Ergebnis vom Typ: `(a -> b) -> (a -> c)`

Funktionen höherer Ordnung: curry




```
curry :: ((a,b) -> c) -> a -> b -> c
curry f = g
          where g x y = f (x,y)
```

```
uncurry :: (a -> b -> c) -> (a,b) -> c
uncurry g = f
            where f (x,y) = g x y
```

Funktionen höherer Ordnung: map

```
suclist :: [Int] -> [Int]
suclist []       = []
suclist (x:xs)   = suc x : suclist xs
```

```
sqrtlist :: [Float] -> [Float]
sqrtlist []       = []
sqrtlist (x:xs)   = sqrt x : sqrtlist xs
```

$$\texttt{suclist}\ [x_1, \ldots, x_n] = [\texttt{suc}\ x_1, \ldots, \texttt{suc}\ x_n]$$
$$\texttt{sqrtlist}\ [x_1, \ldots, x_n] = [\texttt{sqrt}\ x_1, \ldots, \texttt{sqrt}\ x_n]$$
$$\texttt{map g}\ [x_1, \ldots, x_n] = [\texttt{g}\ x_1, \ldots, \texttt{g}\ x_n]$$

```
f :: [a] -> [b]
f []     = []
f (x:xs) = g x : f xs
```

```
map :: (a -> b) -> [a] -> [b]
map g []     = []
map g (x:xs) = g x : map g xs
```

Funktionen höherer Ordnung: map

```
suclist :: [Int] -> [Int]
suclist = map suc
```

```
sqrtlist :: [Float] -> [Float]
suclist = map sqrt
```

$$\texttt{suclist}\ [x_1, \ldots, x_n] = [\texttt{suc}\ x_1, \ldots, \texttt{suc}\ x_n]$$
$$\texttt{sqrtlist}\ [x_1, \ldots, x_n] = [\texttt{sqrt}\ x_1, \ldots, \texttt{sqrt}\ x_n]$$
$$\texttt{map g}\ [x_1, \ldots, x_n] = [\texttt{g}\ x_1, \ldots, \texttt{g}\ x_n]$$

```
f :: [a] -> [b]
f []     = []
f (x:xs) = g x : f xs
```

```
map :: (a -> b) -> [a] -> [b]
map g []     = []
map g (x:xs) = g x : map g xs
```

Funktionen höherer Ordnung: `filter`

```
dropEven :: [ Int ] -> [ Int ]
dropEven [] = []
dropEven (x:xs) |  odd  x    = x : dropEven xs
                | otherwise = dropEven xs
```

```
dropUpper :: [ Char ] -> [ Char ]
dropUpper [] = []
dropUpper (x:xs) | isLower x = x : dropUpper xs
                 | otherwise = dropUpper xs
```

```
f :: [a] -> [a]
f [] = []
f (x:xs) |    g  x  = x : f xs
         | otherwise = f xs
```

```
filter :: (a -> Bool) -> [a] -> [a]
filter g [] = []
filter g (x:xs) | g x       = x : filter g xs
                | otherwise = filter g xs
```

Funktionen höherer Ordnung: `filter`

```
dropEven :: [ Int ] -> [ Int ]
dropEven = filter  odd
```

```
dropUpper :: [ Char ] -> [ Char ]
dropUpper = filter isLower
```

```
f :: [a] -> [a]
f [] = []
f (x:xs) |     g  x  = x : f xs
         | otherwise = f xs
```

```
filter :: (a -> Bool) -> [a] -> [a]
filter g [] = []
filter g (x:xs) | g x       = x : filter g xs
                | otherwise = filter g xs
```

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Nicht-strikte Auswertung

```
infinity :: Int
infinity = infinity + 1

mult :: Int -> Int -> Int
mult 0      y = 0
mult (x+1)  y = y + mult x y
```

```
mult 0 infinity          = 0
```

```
mult infinity 0          Terminiert nicht!
```

```
0 * infinity             Terminiert nicht!
```

Unendliche Datenobjekte

```
from :: Int -> [Int]
from x = x : from (x+1)
```

```
take :: Int -> [a] -> [a]
take 0     _      = []
take _     []     = []
take (n+1) (x:xs) = x : take n xs
```

```
    take 2 (from 5)

=   take 2 (5 : from 6)

=   5 : take 1 (from 6)

=   5 : take 1 (6 : from 7)

=   5 : 6 : take 0 (from 7)

=   5 : 6 : []

=   [5,6]
```

Sieb des Eratosthenes

1. Erstelle Liste aller natürlichen Zahlen ab 2.
2. Markiere die erste unmarkierte Zahl in der Liste.
3. Streiche alle Vielfachen der letzten markierten Zahl.
4. Gehe zurück zu Schritt 2.

```
drop_mult :: Int -> [Int] -> [Int]
drop_mult x xs = filter (\y -> mod y x /= 0) xs
```

```
dropall :: [Int] -> [Int]
dropall (x:xs) = x : dropall (drop_mult x xs)
```

```
primes :: [Int]
primes = dropall (from 2)
```

Sieb des Eratosthenes

```
primes = [2,3,5,7,11,13,17,19,23,29,31,...
```

```
take 5 primes = [2,3,5,7,11]
```

```
drop_mult :: Int -> [Int] -> [Int]
drop_mult x xs = filter (\y -> mod y x /= 0) xs
```

```
dropall :: [Int] -> [Int]
dropall (x:xs) = x : dropall (drop_mult x xs)
```

```
primes :: [Int]
primes = dropall (from 2)
```