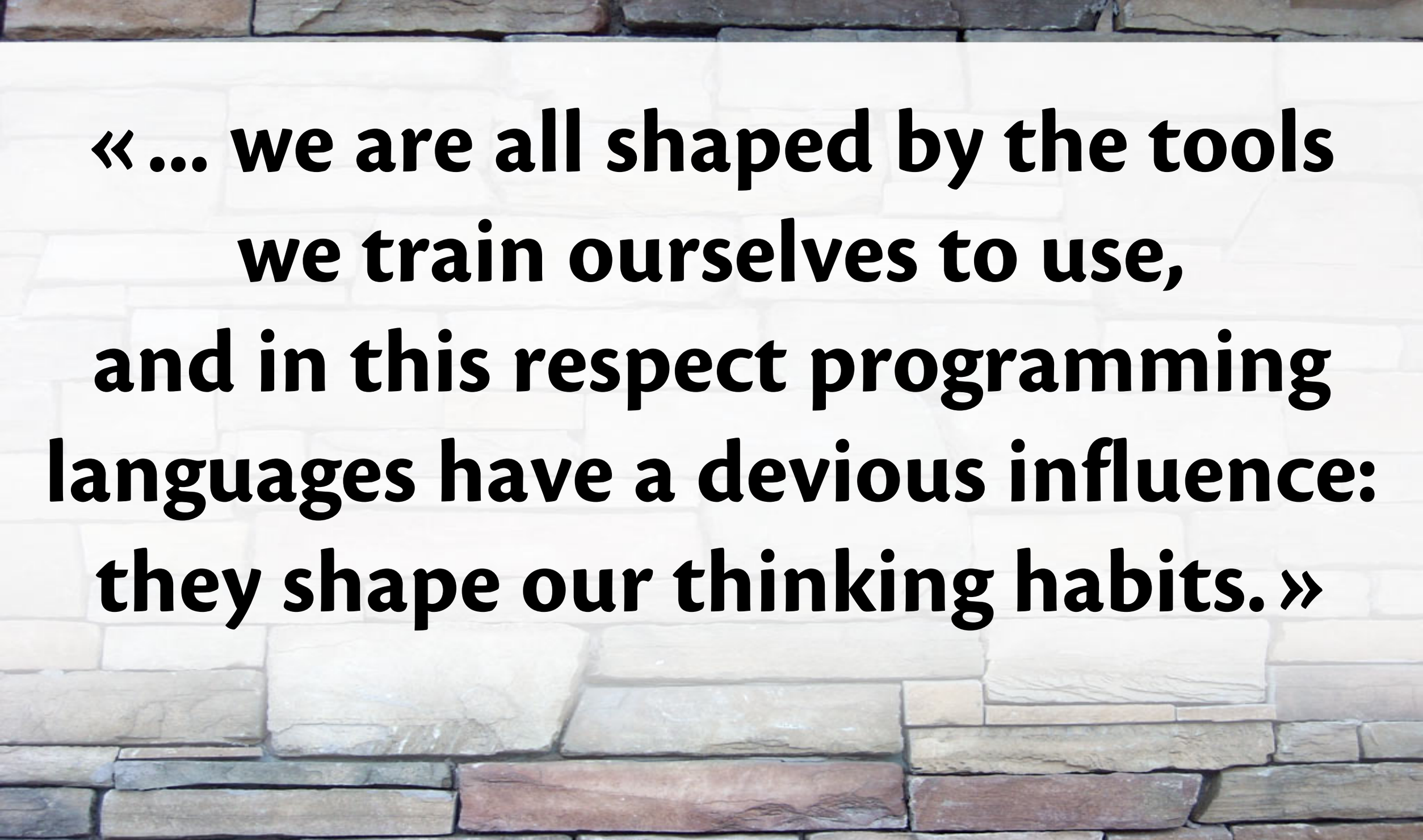
« It is not only the violinist who is shaped by his violin ... »

(wrote Edsger W. Dijkstra in 2001)


« ... we are all shaped by the tools
we train ourselves to use,
and in this respect programming
languages have a devious influence:
they shape our thinking habits. »


A Superficial Exploration
of Haskell

Haskell

is a general-purpose programming language

is especially well-suited for writing parsers / compilers / DSLs

is especially well-suited for prototyping complex software in quick iterations

Haskell

has been popular in academia for some time

is becoming increasingly popular in the software industry

Key Features of Haskell

functional and declarative

highly composable core

encourages the use of concise code to describe the problem, not the solution

your list is your iteration

Key Features of Haskell

lazy by default
(separates equation from execution)

clean separation of concerns:

- pure functional core
  (no side-effects here)
- imperative shell for I/O
  (no algorithms here)

Key Features of Haskell

well-typed-ness and type inference

(a skilled Haskeller encodes problem domain invariants in the type system, so that entire classes of potential bugs will be compile-time errors instead of runtime exceptions that slipped through the cracks in your test suite)

Cultural shock in 3... 2... 1...

Here's a trivial snippet of code in Python:

```
>>> x = 1
>>> x = x + 1
>>> x
2
>>>
```

Nothing could be simpler!

Naively port it to Haskell ...

... expect sunshine and flying colors ...

```
λ: let x = 1
λ: let x = x + 1
λ: x
^CInterrupted.
λ:
```

Huh? What just happened?!?!

To emulate mutation in Haskell ...

```
λ: let x = 1
λ: x <- return $ x + 1
λ: x
2
λ:
```

Laziness

Quick recap of the "map" function

```
λ: let list = [20..30]
λ: list
[20,21,22,23,24,25,26,27,28,
 29,30]
λ: map (+1) list
[21,22,23,24,25,26,27,28,29,
 30,31]
λ:
```

```
λ: let list1 = [20..70]
λ: let list2 = map (+1) list1
λ: :sprint list1
list1 = _
λ: :sprint list2
list2 = _
λ:
λ: head list2
21
λ: :sprint list1
list1 = 20 : _
λ: :sprint list2
list2 = 21 : _
```

```
λ: take 5 list2
[21,22,23,24,25]
λ: :sprint list1
list1 = 20 : 21 : 22 : 23 : 24 : _
λ: :sprint list2
list2 = 21 : 22 : 23 : 24 : 25 : _
```

```
λ: list2 !! 17
38
λ: :sprint list1
list1 = 20 : 21 : 22 : 23 : 24 : 25 : 26 : 27 : 28 : 29 :
        30 : 31 : 32 : 33 : 34 : 35 : 36 : 37 : _
λ: :sprint list2
list2 = 21 : 22 : 23 : 24 : 25 : _ : _ : _ : _ : _ :
        _ : _ : _ : _ : _ : _ : _ : 38 : _
```

```
λ: length list2
51
λ: :sprint list1
list1 = [20,21,22,23,24,25,26,27,28,29,
         30,31,32,33,34,35,36,37,38,39,
         40,41,42,43,44,45,46,47,48,49,
         50,51,52,53,54,55,56,57,58,59,
         60,61,62,63,64,65,66,67,68,69,70]
λ: :sprint list2
list2 = [21,22,23,24,25,_,_,_,_,_,
         _,_,_,_,_,_,_,_,38,_,_,
         _,_,_,_,_,_,_,_,_,_,_,
         _,_,_,_,_,_,_,_,_,_,_,
         _,_,_,_,_,_,_,_,_,_,_,_]
```

```
λ: sum list2
2346
λ: :sprint list2
list2 = [21,22,23,24,25,26,27,28,29,30,
         31,32,33,34,35,36,37,38,39,40,
         41,42,43,44,45,46,47,48,49,50,
         51,52,53,54,55,56,57,58,59,60,
         61,62,63,64,65,66,67,68,69,70,71]
```

How to write basic Haskell

Encapsulate:

- sequencing
- decision
- iteration

in functional abstractions.

Sequencing statement execution in Python

```
>>> x = 1
>>> y = x * 5
>>> z = y + 3
>>> z
8
>>>
```

Sequencing expression evaluation in Haskell

```
λ: let x = 1
λ: let f = (+3) . (*5)
λ:
λ: f 1
8
λ:
```

Deciding between statement executions in Python

```
>>> x = 1
>>> y = 2
>>> if x == y:
...     print 'equal'
... else:
...     print 'not equal'
...
not equal
>>>
```

Haskell says:

What's wrong with this picture (from a separation-of-concerns perspective)?

Deciding between expression evaluations in Python

```
>>> x = 1
>>> y = 2
>>> z = 'equal' if x == y else 'not equal'
>>> z
'not equal'
>>>
```

Deciding between expression evaluations in Haskell

```
λ: let x = 1
λ: let y = 2
λ: let z = if x == y then "equal" else "not equal"
λ: z
"not equal"
λ:
```

Flavors of iteration you'll encounter in Haskell

arranged according to
what kind of input is available and
what kind of output is desired

Finite loop flavor #1

Available input:

- a list of scalar values
- a function of one argument

Desired output:

- a list of scalar values

Use "map"

(Also, your list is your iteration.)

Finite loop flavor #2

Available input:

- a list of scalar values
- a predicate

Desired output:

- a list of scalar values

Use "filter"

(Also, your list is your iteration.)

Finite loop flavor #3

Available input:

- exactly one scalar value
- a list of functions
  of one argument each

Desired output:

- a list of scalar values

Use "<*>"

(An example will follow shortly.)

(Also, your list is your iteration.)

Finite loop flavor #4

Available input:

- a list of scalar values
- a function of two arguments
- the initial value of an accumulator (a scalar value)

Desired output:

- the final value of the accumulator (a scalar value that absorbs the entire contents of the input list)

Finite loop flavor #4

Use "foldl"

(An example will follow shortly.)

(Also, your list is your iteration.)

Finite loop flavor #5

Available input:

- a list of scalar values
- a function of two arguments
- the initial value
  of an accumulator
  (a scalar value)

Desired output:

- a list containing
  a "progress report"
  (what did the
  accumulator look like
  each step along the
  way?)

Finite loop flavor #5

Use "scanl"

(An example will follow shortly.)

(Also, your list is your iteration.)

(Potentially) endless loop flavor #1

Available input:

- **the initial value of an accumulator (a scalar value)**
- **a successor function**
- **a predicate (a.k.a. exit condition)**

Desired output:

- **the final value of the accumulator after however many successive function applications**

(Potentially) endless loop flavor #1

Use "until"

(An example will follow shortly.)

(OK, list ≠ iteration. Just this once.)

(Potentially) endless loop flavor #2

Available input:

- the initial value of an accumulator (a scalar value)
- a successor function
- a predicate (a.k.a. exit condition)

Desired output:

- a list containing a "progress report" (what did the accumulator look like after each successive function application?)

(Potentially) endless loop flavor #2

Use "unfoldr"

(An example will follow shortly.)

(Also, your list is your iteration.)

Flavors of iteration you'll encounter in Haskell

here come the promised examples

Using "<*>"
(finite loop flavor #3)

```
λ: let function_list_1 = [(+2),(*3),(^2)]
λ: let function_list_2 = [(*5),(+7),(*4),(subtract 10)]
λ: let i = 12
λ: import Control.Applicative
λ: function_list_1 <*> [i]
[14,36,144]
λ: function_list_2 <*> [i]
[60,19,48,2]
λ:
```

Using "foldl"
(finite loop flavor #4)

```
λ: foldl (+) 5 [50..70]
1265
```

In Python we'd write:

```
>>> input_list = range(50,71)
>>> accumulator = 5
>>> for i in input_list:
...         accumulator += i
...
>>> accumulator
1265
```

Using "scanl" (finite loop flavor #5)

```
λ: scanl (+) 5 [50..70]
[5,55,106,158,211,265,
 320,376,433,491,550,610,
 671,733,796,860,925,991,
 1058,1126,1195,1265]
```

In Python we'd write:

```
>>> input_list = range(50,71)
>>> accumulator = 5
>>> ol = [accumulator]
>>> for i in input_list:
...     accumulator += i
...     ol.append(accumulator)
...
>>> ol
[5, 55, 106, 158, 211, 265,
 320, 376, 433, 491, 550, 610,
 671, 733, 796, 860, 925, 991,
 1058, 1126, 1195, 1265]
```

Using "until" (endless loop flavor #1)

```
λ: until (>100) (*2) 1
128
```

In Python we'd write:

```
>>> def succf(x):
...     return x * 2
...
>>> acc = 1
>>> while True:
...     acc = succf(acc)
...     if acc > 100:
...         break
...
>>> acc
128
```

Using "unfoldr" (endless loop flavor #2)

```
λ: :{
   let operate_on x =
       if x > 100
       then
         Nothing
       else
         Just (x, x * 2)
   :}
λ: unfoldr operate_on 1
[1,2,4,8,16,32,64]
```

In Python we'd write:

```
>>> def succf(x):
...     return x * 2
...
>>> acc = 1
>>> ol = [accumulator]
>>> while True:
...     acc = succf(acc)
...     if acc > 100:
...         break
...     ol.append(acc)
...
>>> ol
[1, 2, 4, 8, 16, 32, 64]
```

Flavors of iteration you'll encounter in Haskell

map, filter, <*>, foldl, scanl, until, unfoldr

Follow me on GitHub

github.com/dserban

lambda.rosedu.org