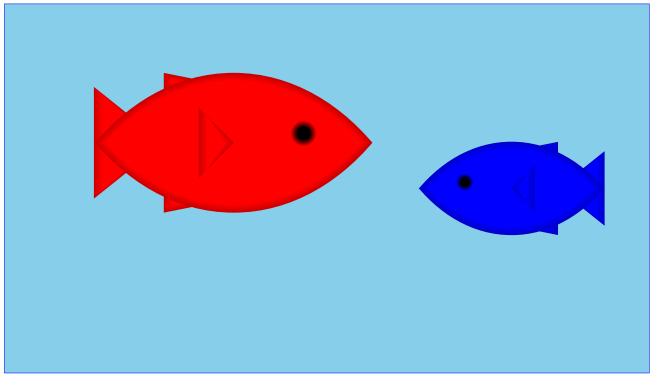
Aquarium

Our zoo was so successful, let’s start an aquarium



For a fish, we only care about its weight, so for two fish:

```
; An aquarium is
;  (make-aq num num)
(define-struct aq (first second))
```

Aquarium Template

```
; An aquarium is
;  (make-aq num num)
```

Generic template:

```
; func-for-aq : aquarium -> ...
; (define (func-for-aq a)
;   ... (aq-first a) ... (aq-second a) ...)
```

Aquarium Template

```
; An aquarium is
;  (make-aq num num)
```

Generic template:

```
; func-for-aq : aquarium -> ...
; (define (func-for-aq a)
;    ... (aq-first a) ... (aq-second a) ...)
```

```
  ; aq-weight : aquarium -> num
  (define (aq-weight a)
    (+ (aq-first a) (aq-second a)))

  (aq-weight (make-aq 7 8)) "should be" 15
```

Aquarium Template

```
; An aquarium is
;  (make-aq num num)
```

Generic template:

```
; func-for-aq : aquarium -> ...
; (define (func-for-aq a)
;    ... (aq-first a) ... (aq-second a) ...)
```

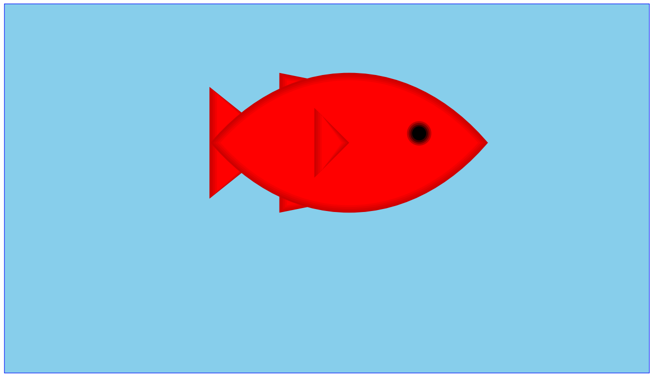
```
; aq-weight : aquarium -> num
(define (aq-weight a)
  (+ (aq-first a) (aq-second a)))

(aq-weight (make-aq 7 8)) "should be" 15
```

And so on, for many other simple aquarium functions...

Tragedy Strikes the Aquarium

Poor blue fish... now we have only one



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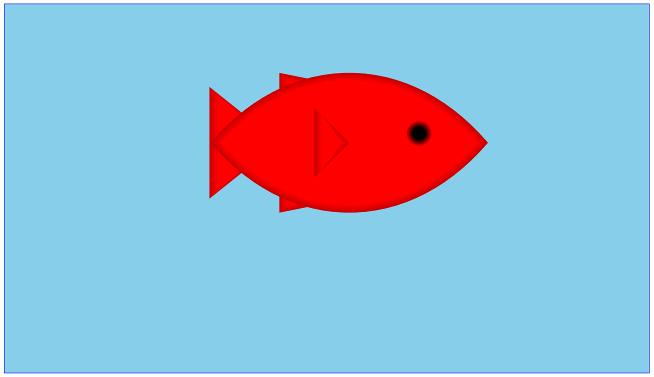


Worse, we have to re-write all our functions...

```
; An aquarium is
;  (make-aq num)
(define-struct aq (first))
```

Aquarium Template, Revised

```
; An aquarium is
;  (make-aq num)

; func-for-aq : aquarium -> ...
; (define (func-for-aq a)
;   ... (aq-first a) ...)
```

Aquarium Template, Revised

```
   ; An aquarium is
   ;  (make-aq num)

   ; func-for-aq : aquarium -> ...
   ; (define (func-for-aq a)
   ;    ... (aq-first a) ...)


; aq-weight : aquarium -> num
(define (aq-weight a)
  (aq-first a))

(aq-weight (make-aq 7)) "should be" 7
```

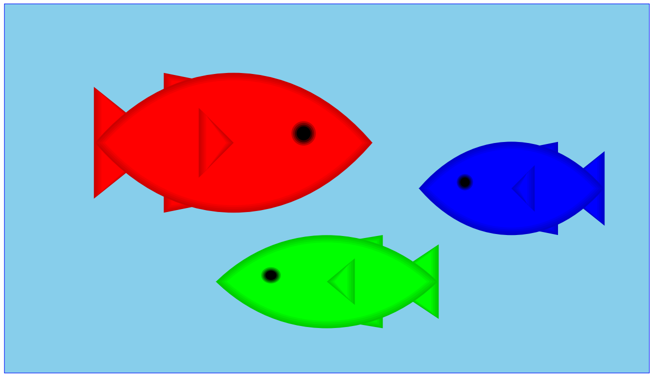
Aquarium Template, Revised

```
   ; An aquarium is
   ;  (make-aq num)

   ; func-for-aq : aquarium -> ...
   ; (define (func-for-aq a)
   ;   ... (aq-first a) ...)


; aq-weight : aquarium -> num
(define (aq-weight a)
  (aq-first a))

(aq-weight (make-aq 7)) "should be" 7
```

And so on, for **all** of the aquarium functions...

The Aquarium Expands

Hooray, we have two new fish!



The Aquarium Expands

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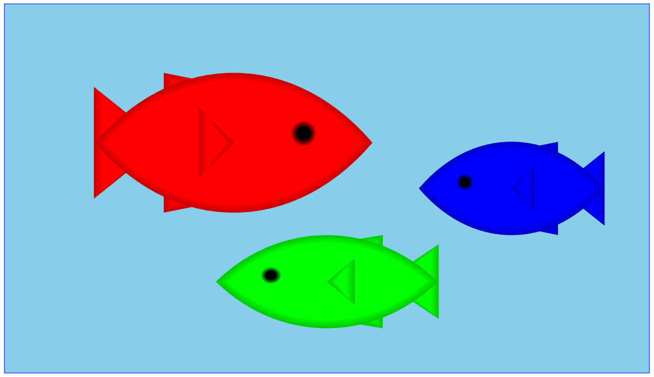


Unfortunately, we have to re-re-write all our functions...

```
; An aquarium is
;  (make-aq num num num)
(define-struct aq (first second third))
```

A Flexible Aquarium Representation

Our data choice isn’t working

- An aquarium isn’t just 1 fish, 2 fish, or 100 fish — it’s a collection containing an arbitrary number of fish
- No data definition with just 1, 2, or 100 numbers will work

To represent an aquarium, we need a ***list*** of numbers

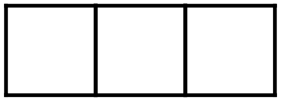
We don’t need anything new in the language, just a new idea

Structs as Boxes

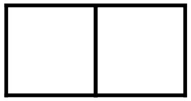
Pictorially,

- **`define-struct`** lets us define a new kind of box
- The box can have as many compartments as we want, but we have to pick how many, once and for all

```
(define-struct snake (name weight food))
```

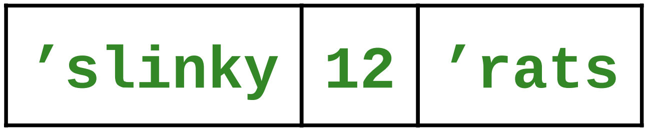
⇒ 

```
(define-struct ant (weight loc))
```

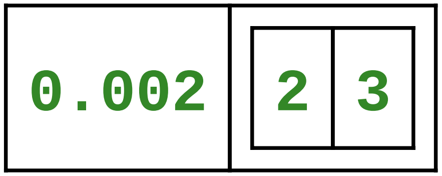
⇒ 

Boxes Stretch

The boxes stretch to fit any one thing in each slot:


'slinky 12 'rats

Even other boxes:


0.002 2 3

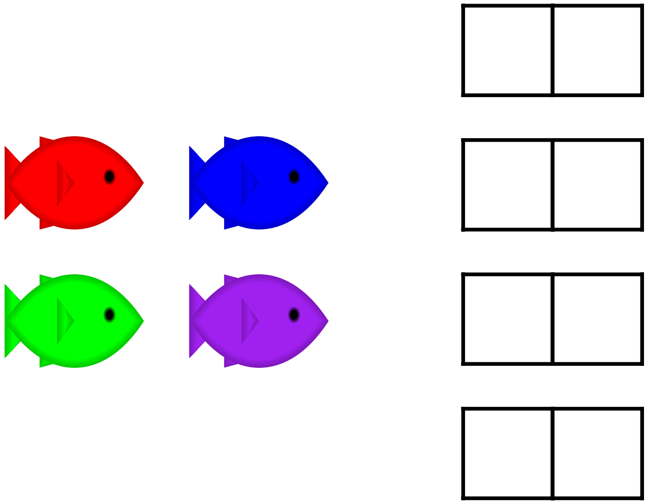
Still, the number of slots is fixed

Packing Boxes

Suppose that

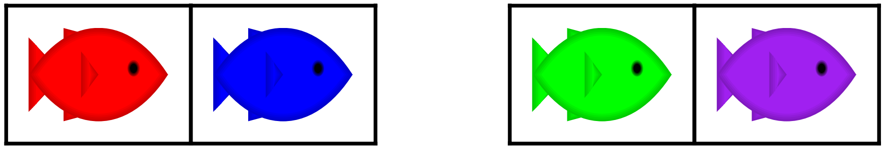
- You have four things to pack as one
- You only have 2-slot boxes
- Every slot must contain exactly one thing

How can you create a single package?



Packing Boxes

This isn’t good enough



because it’s still two boxes...

Packing Boxes

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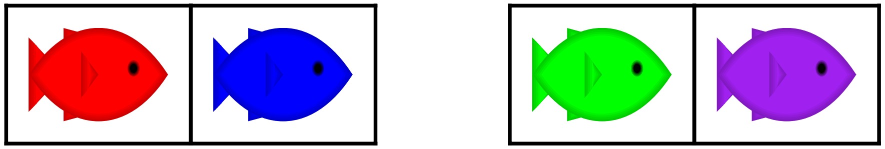

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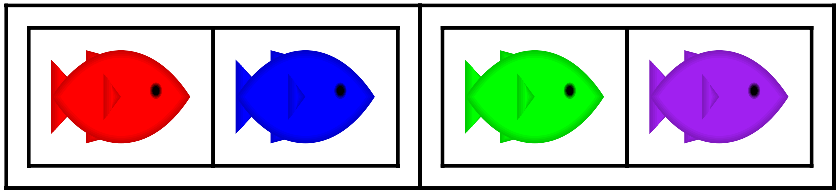
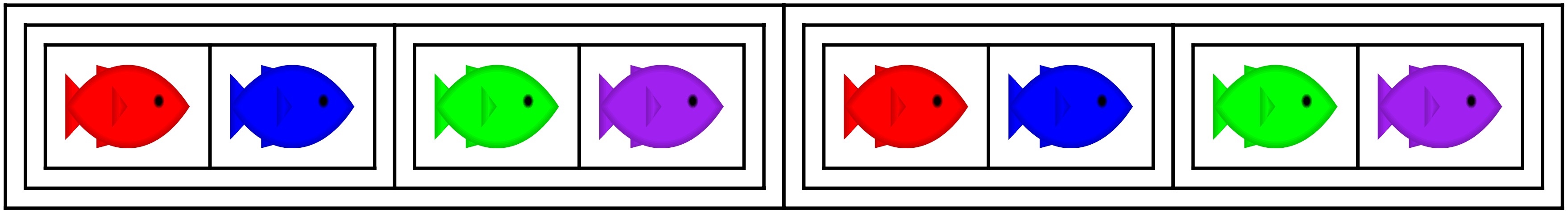
But this works!



Packing Boxes

And here’s 8 fish:



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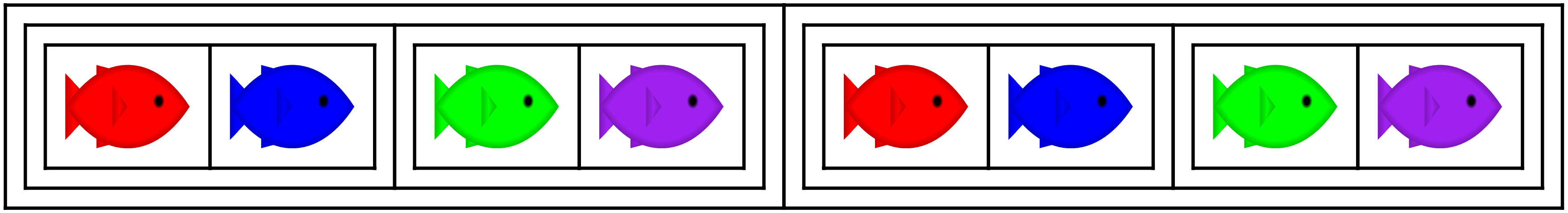
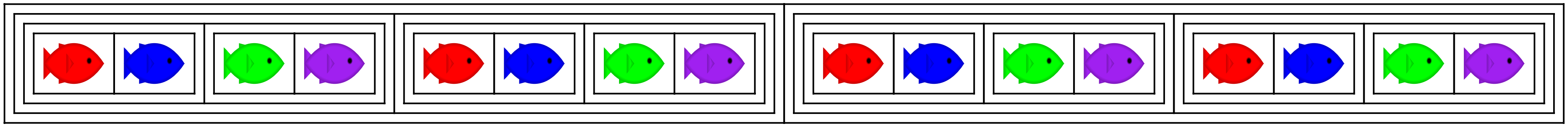


And here’s 16 fish!



Packing Boxes

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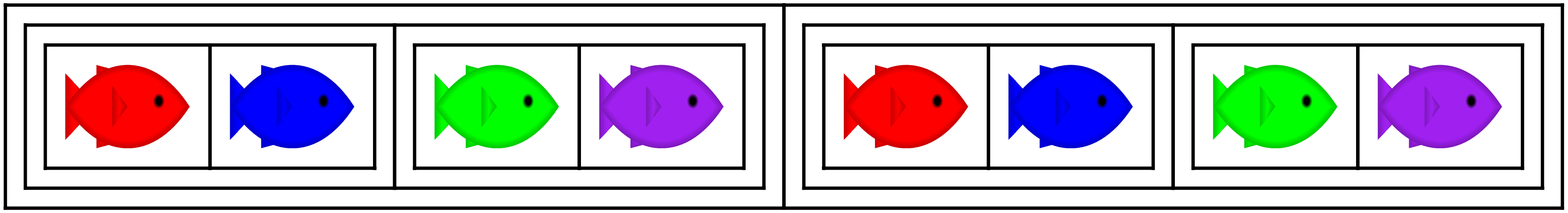

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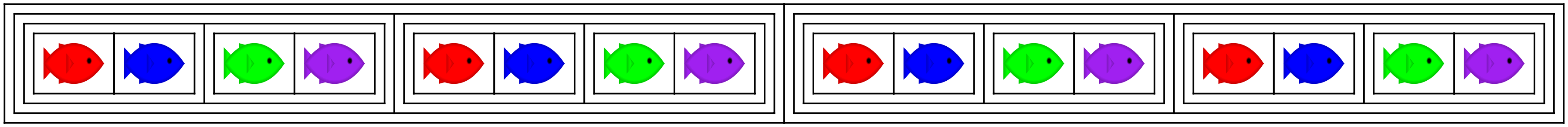

But what if we just add 1 fish, instead of doubling the fish?

But what if we have 0 fish?

General Strategy for Packing Boxes

Here’s a general strategy:

- For 0 fish, use `empty`
- If you have a package and a new fish, put them together

To combine many fish, start with `empty` and add fish one at a time

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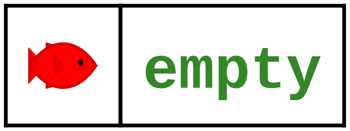

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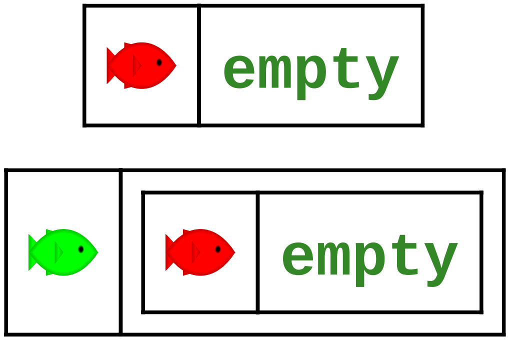

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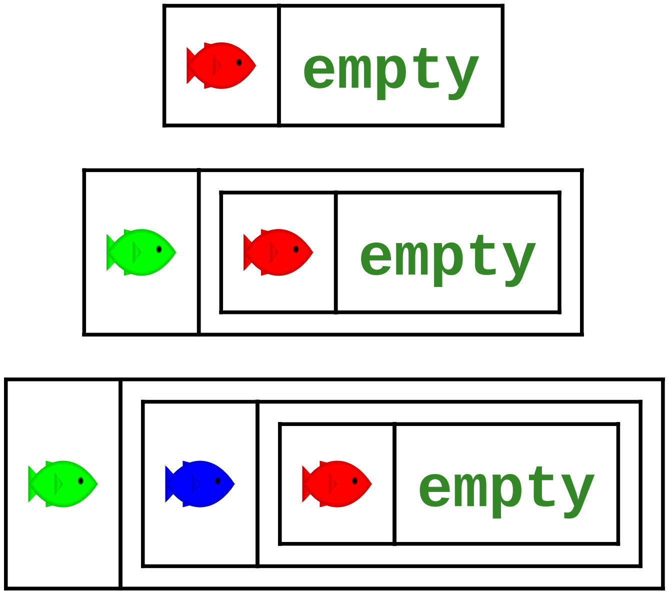

General Strategy for a List of Numbers

To represent the aquarium as a list of numbers, use the same idea:

- For 0 fish, use **`empty`**
- If you have a list and a number, put them together with **`make-bigger-list`**

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```
empty
```

```
(make-bigger-list 10 empty)
```

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```
empty
```

```
(make-bigger-list 10 empty)
```

```
(make-bigger-list 5 (make-bigger-list 10 empty))
```

General Strategy for a List of Numbers

To represent the aquarium as a list of numbers, use the same idea:

- For 0 fish, use `empty`
- If you have a list and a number, put them together with `make-bigger-list`

```
empty

(make-bigger-list 10 empty)

(make-bigger-list 5 (make-bigger-list 10 empty))

(make-bigger-list 7 (make-bigger-list 5 (make-bigger-list 10 empty)))
```

List of Numbers

```
; A list-of-num is either
;  - empty
;  - (make-bigger-list num list-of-num)
(define-struct bigger-list (first rest))
```

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Generic template:

```
; func-for-lon : list-of-num -> ...
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(define (func-for-lon l)
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     ... (bigger-list-rest l)
     ...]))
```

List of Numbers

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     ...]))
```

Aquarium Weight

```
; aq-weight : list-of-num -> num
;  Sums the fish weights in l
(define (aq-weight l)
  ...)
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```
(aq-weight empty) "should be" 0
```

Aquarium Weight

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(define (aq-weight l)
  ...)
```

```
(aq-weight empty) "should be" 0

(aq-weight (make-bigger-list 2 empty))
"should be" 2
```

Aquarium Weight

```
; aq-weight : list-of-num -> num
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(define (aq-weight l)
  ...)
```

```
(aq-weight empty) "should be" 0

(aq-weight (make-bigger-list 2 empty))
"should be" 2

(aq-weight (make-bigger-list 5 (make-bigger-list 2 empty)))
"should be" 7
```

Aquarium Weight

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; aq-weight : list-of-num -> num
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(define (aq-weight l)
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    [(empty? l) ...]
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     ... (bigger-list-first l)
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     ...]))

(aq-weight empty) "should be" 0

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"should be" 2

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"should be" 7
```

Aquarium Weight

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; aq-weight : list-of-num -> num
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(define (aq-weight l)
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    (+ (bigger-list-first l)
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```

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(aq-weight empty) "should be" 0
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```
(aq-weight (make-bigger-list 2 empty))
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```
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Aquarium Weight

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    (+ (bigger-list-first l)
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```

Try examples in the stepper

```
(aq-weight empty) "should be" 0
```

```
(aq-weight (make-bigger-list 2 empty))
"should be" 2
```

```
(aq-weight (make-bigger-list 5 (make-bigger-list 2 empty)))
"should be" 7
```

Shortcuts

The name `make-bigger-list` is awfully long

DrScheme has built-in shorter versions

`make-bigger-list`	⇒	`cons`
`bigger-list-first`	⇒	`first`
`bigger-list-rest`	⇒	`rest`
`bigger-list?`	⇒	`cons?`

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`bigger-list-rest`	⇒	`rest`
`bigger-list?`	⇒	`cons?`

```
(first (cons 1 empty))  →  1

(rest (cons 1 empty))  →  empty

(cons? empty)  →  false
```

Lists using the Shortcuts

```
; A list-of-num is either
;  - empty
;  - (cons num list-of-num)

; aq-weight : list-of-num -> num
(define (aq-weight l)
  (cond
    [(empty? l) 0]
    [(cons? l) (+ (first l)
                  (aq-weight (rest l)))]))

(aq-weight empty) "should be" 0

(aq-weight (cons 5 (cons 2 empty)))
"should be" 7
```

Design Recipe for Lists

Design recipe changes for today:

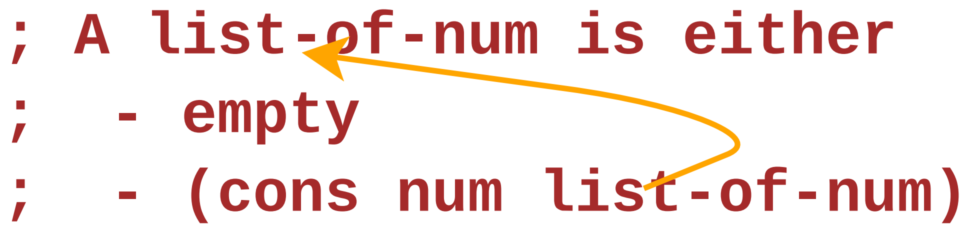
None

Design Recipe for Lists

Design recipe changes for today:

None

Granted, the self-reference was slightly novel...



```
; A list-of-num is either
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```

Recursion

A self-reference in a data definition leads to a ***recursive*** function — one that calls itself

```
(define (aq-weight l)
  (cond
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```

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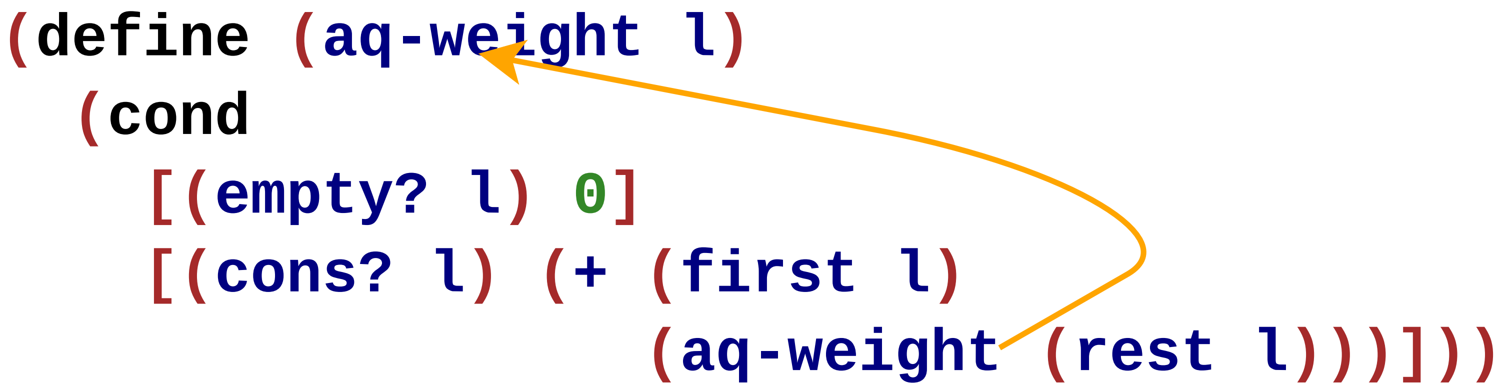

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Recursion is rumored to be a difficult topic...

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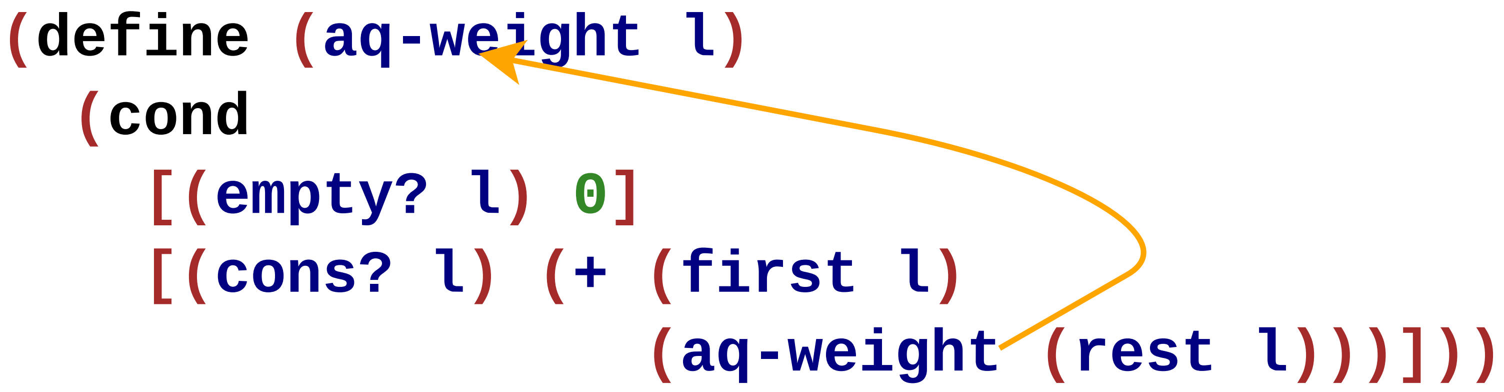

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... but now you know better