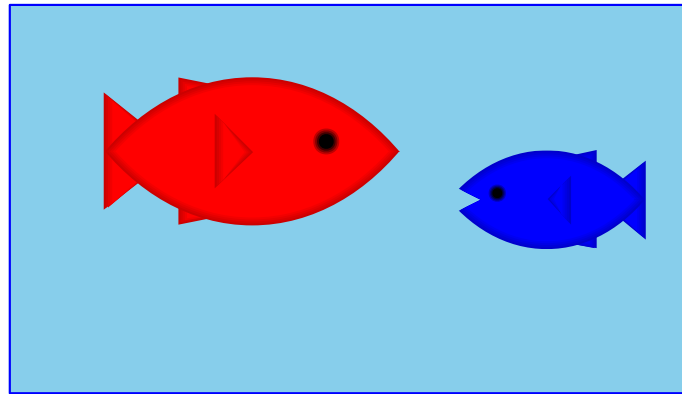


Aquarium

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) ...)
```

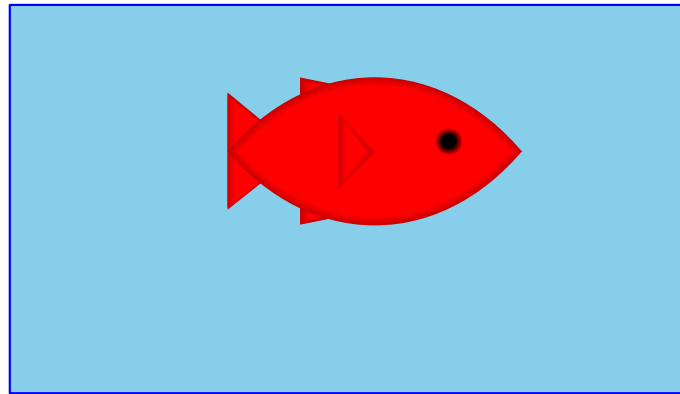
```
; aq-weight : aquarium -> num  
(define (aq-weight a)  
  (+ (aq-first a) (aq-second a)))
```

```
(check-expect (aq-weight (make-aq 7 8)) 15)
```

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

Tragedy Strikes the Aquarium

Poor blue fish... now we have only one



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) ...)
```

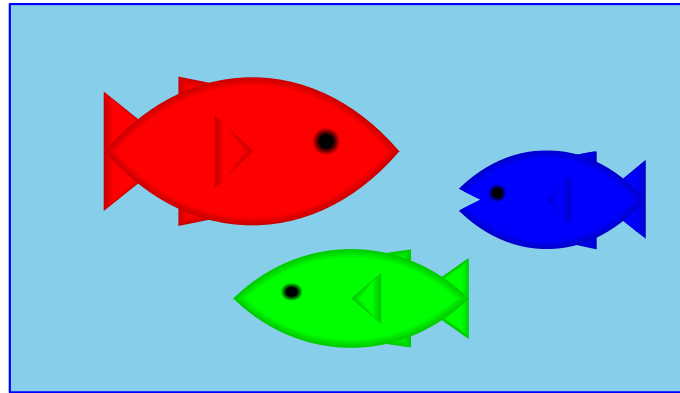
```
; aq-weight : aquarium -> num  
(define (aq-weight a)  
  (aq-first a))
```

```
(check-expect (aq-weight (make-aq 7)) 7)
```

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

The Aquarium Expands

Hooray, we have two new fish!



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

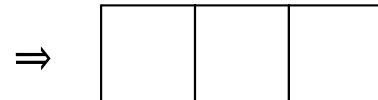
We don't need anything new in the language, just a new idea

Structs as Boxes

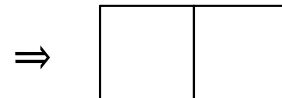
Pictorially,

- `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))
```

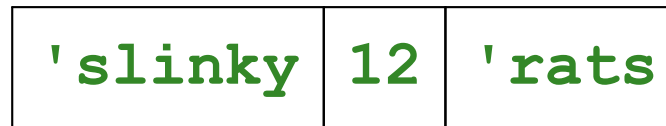


```
(define-struct ant (weight loc))
```

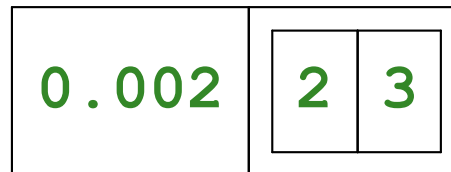


Boxes Stretch

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



Even other boxes:



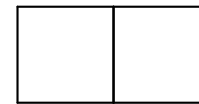
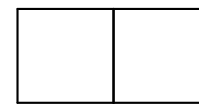
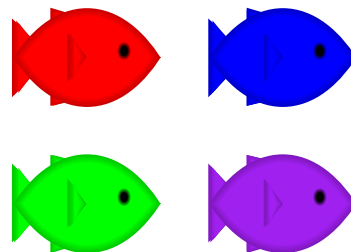
Still, the number of slots is fixed

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?



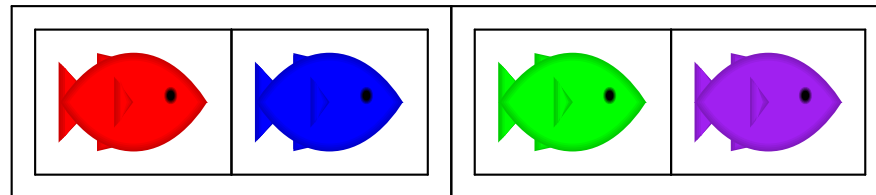
Packing Boxes

This isn't good enough



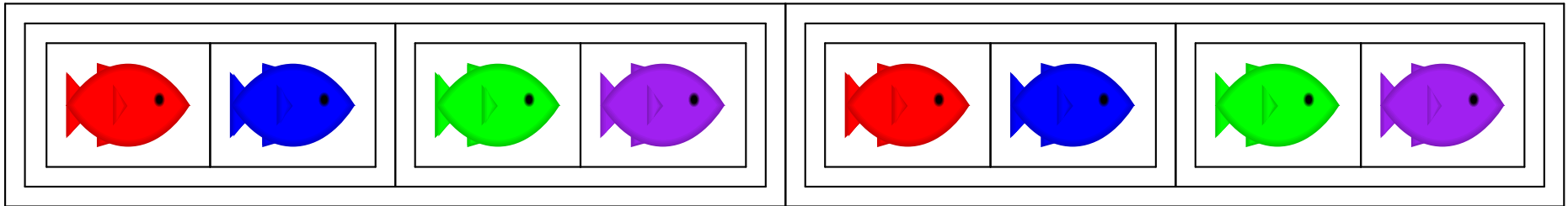
because it's still two boxes...

But this works!

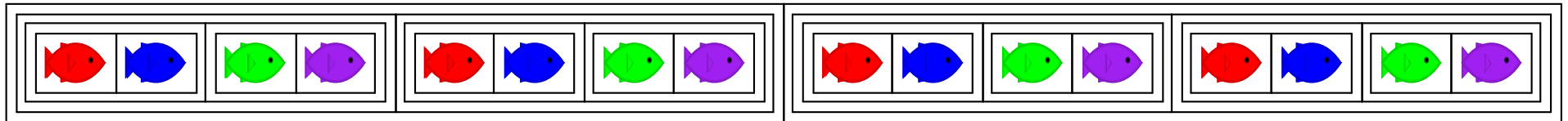


Packing Boxes

And here's 8 fish:



And here's 16 fish!



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

But what if we have 0 fish?

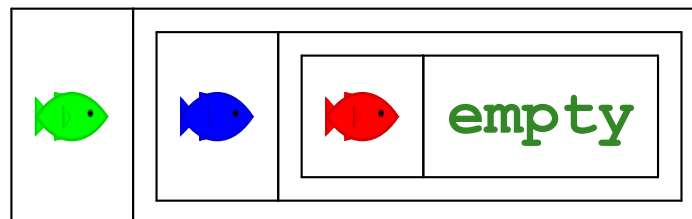
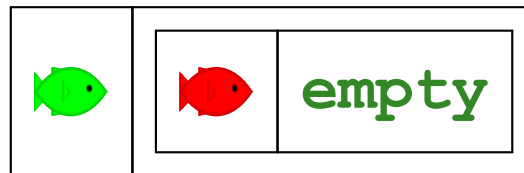
General Strategy for Packing Boxes

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

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))
```

List of Numbers

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

Generic template:

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

List of Numbers

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

Generic template:

```
; func-for-lon : list-of-num -> ...  
(define (func-for-lon l)  
  (cond  
    [(empty? l) ...]  
    [(bigger-list? l) ...]))
```


List of Numbers


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

Generic template:

```
; func-for-lon : list-of-num -> ...  
(define (func-for-lon l)  
  (cond  
    [(empty? l) ...]  
    [(bigger-list? l)  
     ... (bigger-list-first l)  
     ... (bigger-list-rest l)  
     ...]))
```

List of Numbers

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




Generic template:

```
; func-for-lon : list-of-num -> ...  
(define (func-for-lon l)  
  (cond  
    [(empty? l) ...]  
    [(bigger-list? l)  
     ... (bigger-list-first l)  
     ... (bigger-list-rest l)  
     ...]))
```

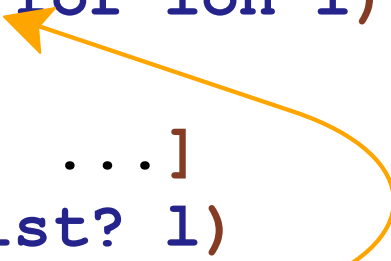
List of Numbers

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



Generic template:

```
; func-for-lon : list-of-num -> ...  
(define (func-for-lon l)  
  (cond  
    [(empty? l) ...]  
    [(bigger-list? l)  
     ... (bigger-list-first l)  
     ... (func-for-lon (bigger-list-rest l))  
     ...]))
```



Aquarium Weight

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

Aquarium Weight

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

```
(check-expect (aq-weight empty) 0)
```

Aquarium Weight

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

```
(check-expect (aq-weight empty) 0)
```

```
(check-expect (aq-weight (make-bigger-list 2 empty))  
  2)
```

Aquarium Weight

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

```
(check-expect (aq-weight empty) 0)
```

```
(check-expect (aq-weight (make-bigger-list 2 empty))  
              2)
```

```
(check-expect (aq-weight (make-bigger-list 5 (make-bigger-list 2 empty)))  
              7)
```

Aquarium Weight

```
; aq-weight : list-of-num -> num
; Sums the fish weights in l
(define (aq-weight l)
  (cond
    [(empty? l) ...]
    [(bigger-list? l)
     ... (bigger-list-first l)
     ... (aq-weight (bigger-list-rest l))
     ...]))

(check-expect (aq-weight empty) 0)

(check-expect (aq-weight (make-bigger-list 2 empty))
              2)

(check-expect (aq-weight (make-bigger-list 5 (make-bigger-list 2 empty)))
              7)
```


Aquarium Weight

```
; aq-weight : list-of-num -> num
; Sums the fish weights in l
(define (aq-weight l)
  (cond
    [(empty? l) 0]
    [(bigger-list? l)
     (+ (bigger-list-first l)
        (aq-weight (bigger-list-rest l)))]))

(check-expect (aq-weight empty) 0)

(check-expect (aq-weight (make-bigger-list 2 empty))
              2)

(check-expect (aq-weight (make-bigger-list 5 (make-bigger-list 2 empty)))
              7)
```

Aquarium Weight

```
; aq-weight : list-of-num -> num
; Sums the fish weights in l
(define (aq-weight l)
  (cond
    [(empty? l) 0]
    [(bigger-list? l)
     (+ (bigger-list-first l)
        (aq-weight (bigger-list-rest l)))])))
```

Try examples in the stepper

```
(check-expect (aq-weight empty) 0)
```

```
(check-expect (aq-weight (make-bigger-list 2 empty))
              2)
```

```
(check-expect (aq-weight (make-bigger-list 5 (make-bigger-list 2 empty)))
              7)
```

Shortcuts

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

DrRacket has built-in shorter versions

<code>make-bigger-list</code>	<code>⇒</code>	<code>cons</code>
<code>bigger-list-first</code>	<code>⇒</code>	<code>first</code>
<code>bigger-list-rest</code>	<code>⇒</code>	<code>rest</code>
<code>bigger-list?</code>	<code>⇒</code>	<code>cons?</code>

`(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)))]))

(check-expect (aq-weight empty) 0)

(check-expect (aq-weight (cons 5 (cons 2 empty)))
              7)
```


Design Recipe for Lists

Design recipe changes for today:

None

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

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



Recursion

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

```
(define (aq-weight l)
  (cond
    [(empty? l) 0]
    [(cons? l) (+ (first l)
                  (aq-weight (rest l)))]))
```

