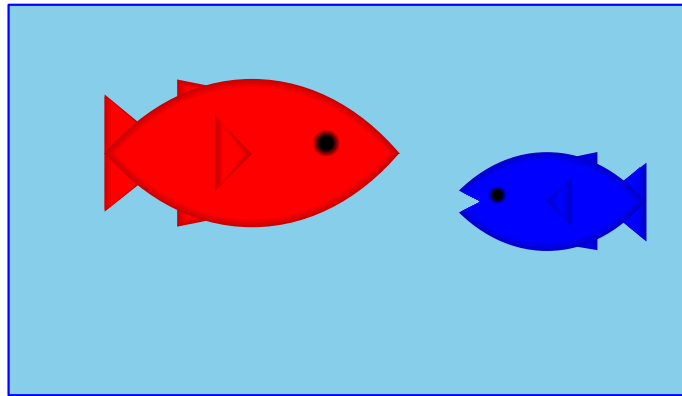


Aquarium

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

Aquarium Template

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

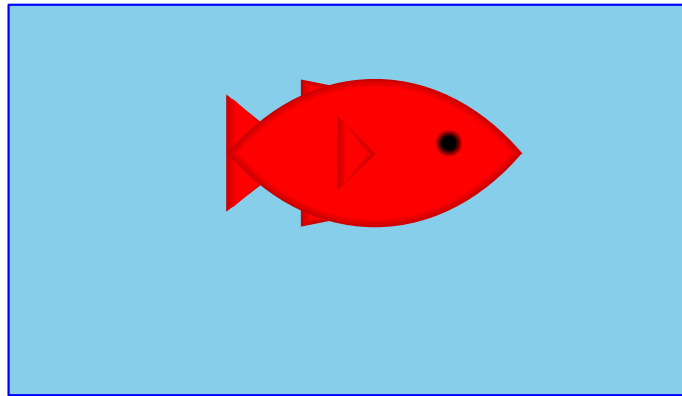
Generic template:

```
; func-for-aq : aquarium -> ...  
;  
; (define (func-for-aq a)  
;   ... (aq-first a) ... (aq-second a) ...)  
  
; aq-weight : aquarium -> num  
(define (aq-weight a)  
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(check-expect (aq-weight (make-aq 7 8)) 15)
```

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

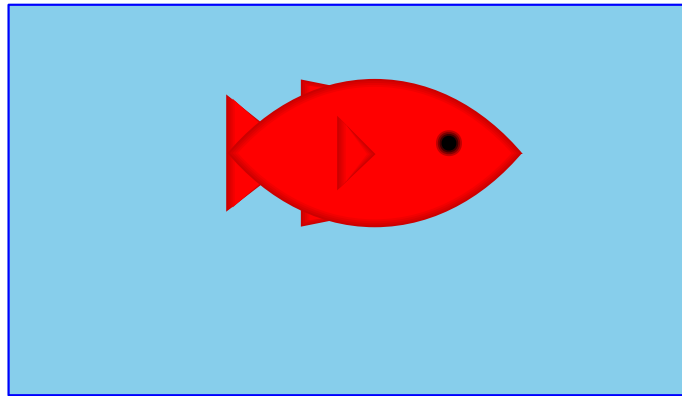
Tragedy Strikes the Aquarium

Poor blue fish... now we have only one



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) ...)  
;
```

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)
```


Aquarium Template, Revised

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

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

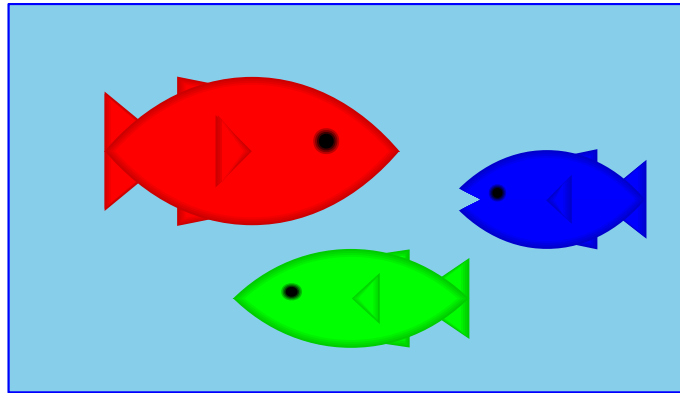
; aq-weight : aquarium -> num
(define (aq-weight a)
  (aq-first a))

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

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

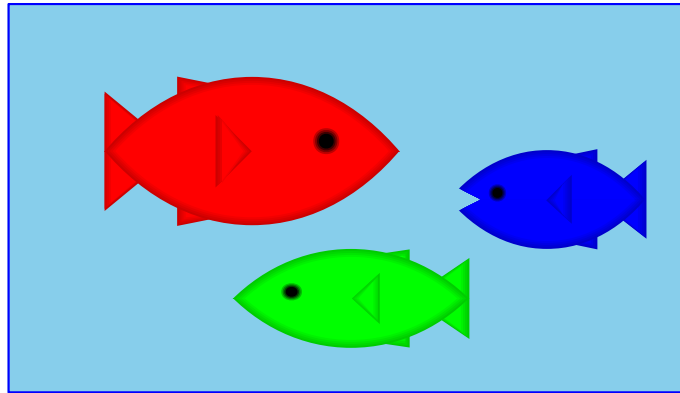
The Aquarium Expands

Hooray, we have two new fish!



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

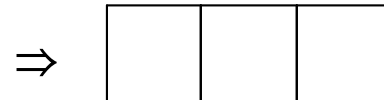
We don't need anything new in the language, just a new idea

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))
```

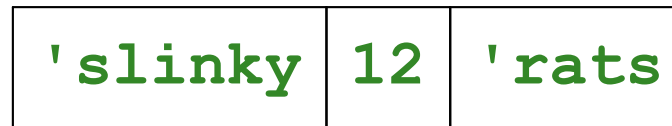


```
(define-struct ant (weight loc))
```

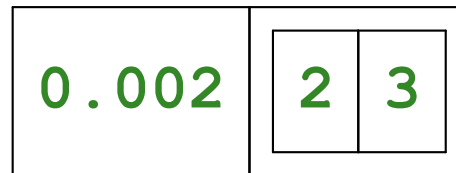


Boxes Stretch

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



Even other boxes:



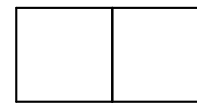
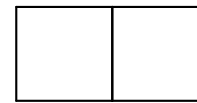
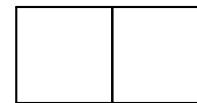
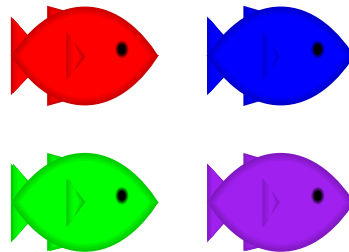
Still, the number of slots is fixed

Packing Boxes

Suppose that

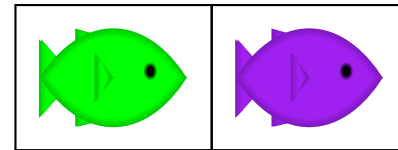
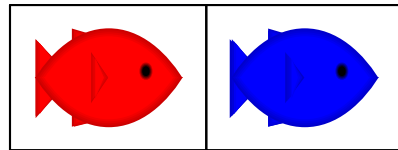
- You have four things to pack as one
- You only have 2-slot boxes
- Every slot must contain exactly one thing

How can you create a single package?



Packing Boxes

This isn't good enough



because it's still two boxes...

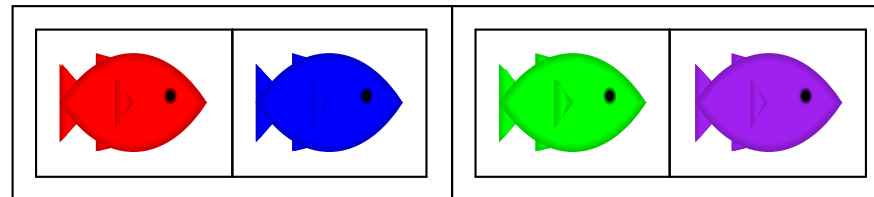
Packing Boxes

This isn't good enough



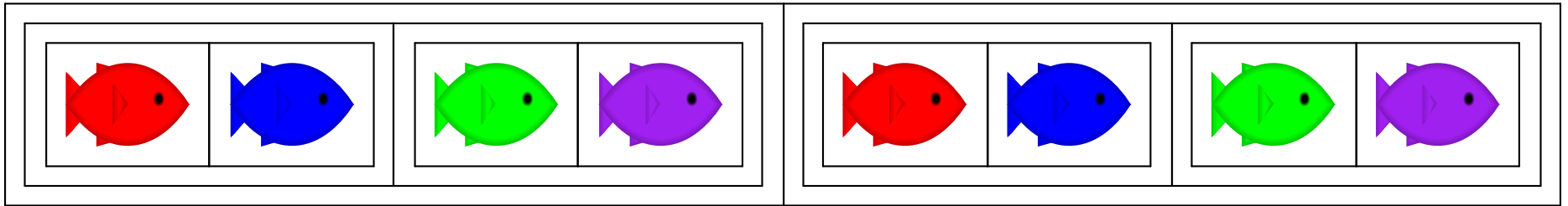
because it's still two boxes...

But this works!



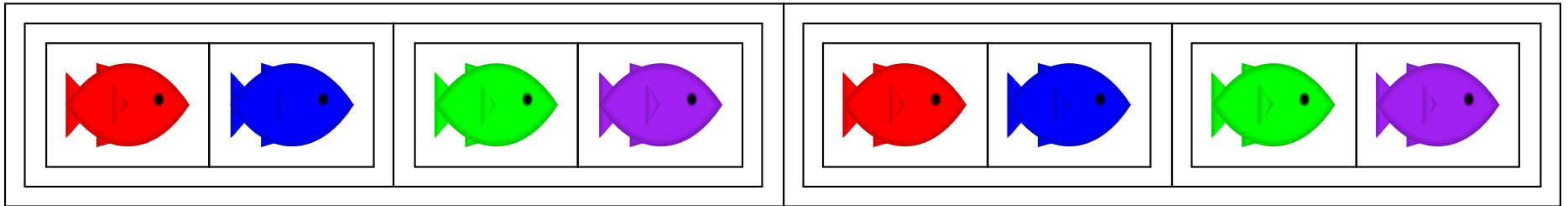
Packing Boxes

And here's 8 fish:

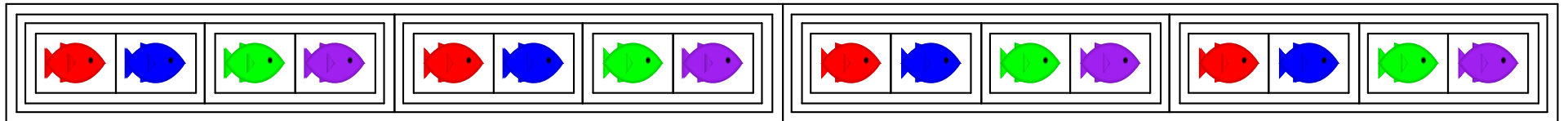


Packing Boxes

And here's 8 fish:

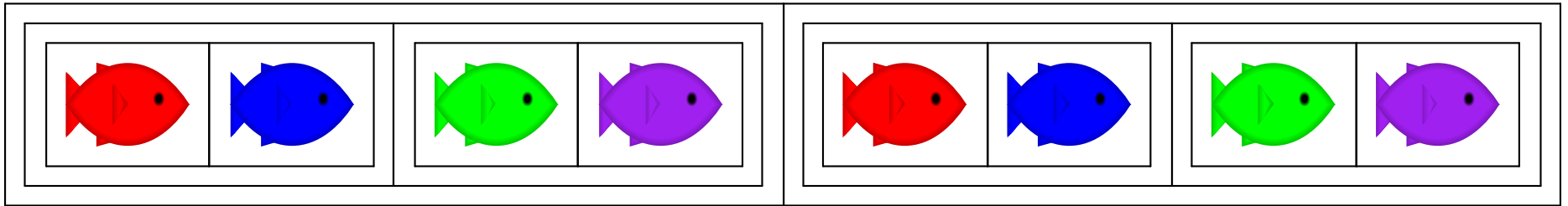


And here's 16 fish!

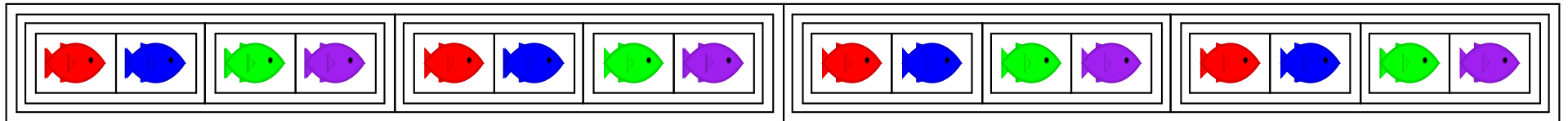


Packing Boxes

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 ' ()
- If you have a package and a new fish, put them together

To combine many fish, start with ' () and add fish one at a time

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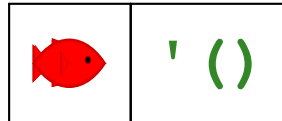
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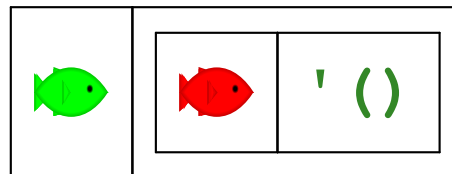
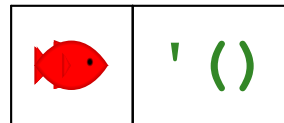
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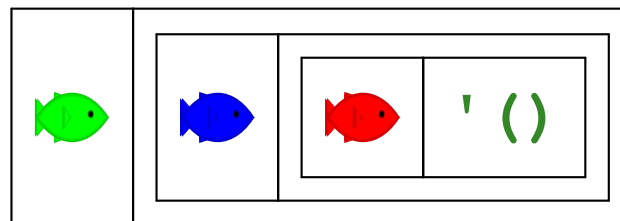
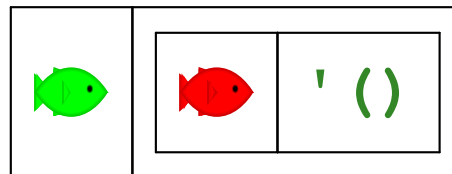
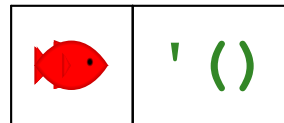
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General Strategy for a List of Numbers

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

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`' ()`

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

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```
' ()
```

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

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

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

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' ()
```

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

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

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

List of Numbers

```
; A list-of-num is either  
; - '()  
; - (make-bigger-list num list-of-num)  
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```
; func-for-lon : list-of-num -> ...  
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  ...)
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```

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     ... (bigger-list-rest l)  
     ...]))
```

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```

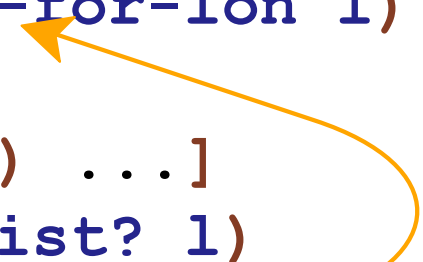
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     ...]))
```



Aquarium Weight

```
; aq-weight : list-of-num -> num  
; Sums the fish weights in l  
(define (aq-weight l)  
  ...)
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(check-expect (aq-weight '()) 0)
```

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  ...)
```

```
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```

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

Aquarium Weight

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; aq-weight : list-of-num -> num
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```

```
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              7)
```


Aquarium Weight

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

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              2)

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              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 '()) 0)

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

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

Shortcuts

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

DrRacket has built-in shorter versions

`make-bigger-list` ⇒ `cons`

`bigger-list-first` ⇒ `first`

`bigger-list-rest` ⇒ `rest`

`bigger-list?` ⇒ `cons?`

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 ' ())) → 1
```

```
(rest (cons 1 ' ())) → ' ( )
```

```
(cons? ' ( )) → #false
```

Lists using the Shortcuts

```
; A list-of-num is either
; - '()
; - (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 '()) 0)

(check-expect (aq-weight (cons 5 (cons 2 '())))
              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  
; - '()  
; - (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)))]))
```

