

Big Fish

A function that gets the big fish (> 5 lbs):

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (cond
       [(> (first l) 5)
        (cons (first l) (big (rest l)))]
       [else (big (rest l))])]))

(check-expect (big '()) '())
(check-expect (big '(7 4 9)) '(7 9))
```

Big Fish

Better with `local`:

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define big-rest (big (rest l)))]
       (cond
         [(> (first l) 5)
          (cons (first l) big-rest)]
         [else big-rest]))]))
```

Big Fish

Better with `local`:

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define big-rest (big (rest l)))]
       (cond
         [(> (first l) 5)
          (cons (first l) big-rest)]
         [else big-rest]))]))]
```

Suppose we also need to find huge fish...

Huge Fish

Huge fish (> 10 lbs):

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define h-rest (huge (rest l)))]
       (cond
         [(> (first l) 10)
          (cons (first l) h-rest)]
         [else h-rest]))]))
```

Huge Fish

Huge fish (> 10 lbs):

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define h-rest (huge (rest l)))]
       (cond
         [(> (first l) 10)
          (cons (first l) h-rest)]
         [else h-rest]))]))
```

How do you suppose I made this slide?

Huge Fish

Huge fish (> 10 lbs):

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define h-rest (huge (rest l)))]
       (cond
         [(> (first l) 10)
          (cons (first l) h-rest)]
         [else h-rest]))]))
```

How do you suppose I made this slide?

Cut and Paste!

The Trouble With Cut and Paste


```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (cond
       [(> (first l) 5)
        (cons (first l) (big (rest l)))]
       [else (big (rest l))])]))
```

cut and paste

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (cond
       [(> (first l) 10)
        (cons (first l) (huge (rest l)))]
       [else (huge (rest l))])]))
```

The Trouble With Cut and Paste

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (cond
       [(> (first l) 5)
        (cons (first l) (big (rest l)))]
       [else (big (rest l))])]))
```




cut and paste

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (cond
       [(> (first l) 10)
        (cons (first l) (huge (rest l)))]
       [else (huge (rest l))])]))
```



The Trouble With Cut and Paste

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (cond
       [(> (first l) 5)
        (cons (first l) (big (rest l)))]
       [else (big (rest l))])]))
```



↙
cut and paste
↘

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (cond
       [(> (first l) 10)
        (cons (first l) (huge (rest l)))]
       [else (huge (rest l))])]))
```



After cut-and-paste, improvement is twice as hard

The Trouble With Cut and Paste

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define big-rest (big (rest l)))]
       (cond
         [(> (first l) 5)
          (cons (first l) big-rest)]
         [else big-rest]))]))
```

cut and paste

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define h-rest (huge (rest l)))]
       (cond
         [(> (first l) 10)
          (cons (first l) h-rest)]
         [else h-rest]))]))
```

The Trouble With Cut and Paste

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define big-rest (big (rest l)))]
       (cond
         [(> (first l) 5)
          (cons (first l) big-rest)]
         [else big-rest]))]))
```



↙
cut and paste
↘

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define h-rest (huge (rest l)))]
       (cond
         [(> (first l) 10)
          (cons (first l) h-rest)]
         [else h-rest]))]))
```

The Trouble With Cut and Paste

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define big-rest (big (rest l)))]
       (cond
         [(> (first l) 5)
          (cons (first l) big-rest)]
         [else big-rest]))]))
```



↙
cut and paste
↘

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define h-rest (huge (rest l)))]
       (cond
         [(> (first l) 10)
          (cons (first l) h-rest)]
         [else h-rest]))]))
```



After cut-and-paste, bugs multiply

The Trouble With Cut and Paste

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define big-rest (big (rest l)))]
       (cond
         [(> (first l) 5)
          (cons (first l) big-rest)]
         [else big-rest]))]))
```



Avoid cut and paste!

cut and paste

```
; list-of-nums -> list-of-nums
(define (huge l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define h-rest (huge (rest l)))]
       (cond
         [(> (first l) 10)
          (cons (first l) h-rest)]
         [else h-rest]))]))
```



After cut-and-paste, bugs multiply

How to Avoid Cut-and-Paste

Start with the original function...

```
; list-of-nums -> list-of-nums
(define (big l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define big-rest (big (rest l)))]
       (cond
         [(> (first l) 5)
          (cons (first l) big-rest)]
         [else big-rest]))]))
```

How to Avoid Cut-and-Paste

...and add arguments for parts that should change

```
; list-of-nums num -> list-of-nums
(define (bigger l n)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r (bigger (rest l) n))]
       (cond
         [(> (first l) n)
          (cons (first l) r)]
         [else r]))]))
```

How to Avoid Cut-and-Paste

...and add arguments for parts that should change

```
; list-of-nums num -> list-of-nums
(define (bigger l n)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r (bigger (rest l) n))]
       (cond
         [(> (first l) n)
          (cons (first l) r)]
         [else r]))]))

(define (big l) (bigger l 5))

(define (huge l) (bigger l 10))
```


Small Fish

Now we want the small fish:

Small Fish

Now we want the small fish:

```
; list-of-nums num -> list-of-nums
(define (smaller l n)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r (smaller (rest l) n))]
       (cond
         [(< (first l) n)
          (cons (first l) r)]
         [else r]))]))

(define (small l) (smaller l 5))
```

Small Fish

Now we want the small fish:

```
; list-of-nums num -> list-of-nums
(define (smaller l n)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r (smaller (rest l) n))]
       (cond
         [(< (first l) n)
          (cons (first l) r)]
         [else r]))]))
(define (small l) (smaller l 5))
```

No! Don't cut and paste!

Sized Fish

```
; list-of-nums num ... -> list-of-nums
(define (sized l n COMP)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r
               (sized (rest l) n COMP))]
           (cond
            [(COMP (first l) n)
             (cons (first l) r)]
            [else r]))]))

(define (bigger l n) (sized l n >))
(define (smaller l n) (sized l n <))
```

Sized Fish

```
; list-of-nums num ... -> list-of-nums
(define (sized l n COMP)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r
               (sized (rest l) n COMP))]
           (cond
            [(COMP (first l) n)
             (cons (first l) r)]
            [else r]))]))

(define (bigger l n) (sized l n >))
(define (smaller l n) (sized l n <))
```

Does this work? What is the signature for `sized`?

Functions as Values

The definition

```
(define (bigger l n) (sized l n >))
```

works because *functions are values*

Functions as Values

The definition

```
(define (bigger l n) (sized l n >))
```

works because *functions are values*

- `10` is a `num`
- `#false` is a `bool`

Functions as Values

The definition

```
(define (bigger l n) (sized l n >))
```

works because *functions are values*

- 10 is a num
- #false is a bool
- < is a (num num -> bool)

Functions as Values

The definition

```
(define (bigger l n) (sized l n >))
```

works because *functions are values*

- 10 is a num
- #false is a bool
- < is a (num num -> bool)

So the signature for sized is

```
; list-of-nums num (num num -> bool)  
; -> list-of-nums
```

Sized Fish

```
; list-of-nums num (num num -> bool)
; -> list-of-nums
(define (sized l n COMP)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r
               (sized (rest l) n COMP))]
           (cond
            [(COMP (first l) n)
             (cons (first l) r)]
            [else r]))]))

(define (tiny l) (sized l 2 <))
(define (medium l) (sized l 5 =))
```

Sized Fish

```
; list-of-nums num (num num -> bool)
; -> list-of-nums
(define (sized l n COMP)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r
               (sized (rest l) n COMP))]
           (cond
            [(COMP (first l) n)
             (cons (first l) r)]
            [else r]))]))
```

How about all fish between 3 and 7 lbs?

Mediumish Fish

```
; num num -> bool
(define (btw-3-and-7 a ignored-zero)
  (and (>= a 3)
        (<= a 7)))

(define (mediumish 1) (sized 1 0 btw-3-and-7))
```

Mediumish Fish

```
; num num -> bool
(define (btw-3-and-7 a ignored-zero)
  (and (>= a 3)
       (<= a 7)))

(define (mediumish 1) (sized 1 0 btw-3-and-7))
```

- Programmer-defined functions are values, too
- Note that the signature of `btw-3-and-7` matches the kind expected by `sized`

Mediumish Fish

```
; num num -> bool
(define (btw-3-and-7 a ignored-zero)
  (and (>= a 3)
       (<= a 7)))

(define (mediumish 1) (sized 1 0 btw-3-and-7))
```

- Programmer-defined functions are values, too
- Note that the signature of `btw-3-and-7` matches the kind expected by `sized`

But the ignored `0` suggests a simplification of `sized`...

A Generic Number Filter

```
; (num -> bool) list-of-num -> list-of-num
(define (filter-nums PRED l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r
               (filter-nums PRED (rest l)))]
       (cond
         [(PRED (first l))
          (cons (first l) r)]
         [else r]))]))
```

A Generic Number Filter

```
; (num -> bool) list-of-num -> list-of-num
(define (filter-nums PRED l)
  (cond
    [(empty? l) '()]
    [(cons? l)
     (local [(define r
                (filter-nums PRED (rest l)))]
       (cond
         [(PRED (first l))
          (cons (first l) r)]
         [else r]))]))

(define (btw-3&7 n) (and (>= n 3) (<= n 7)))
(define (mediumish l) (filter-nums btw-3&7 l))
```


Big and Huge Fish, Again

```
(define (more-than-5 n)
  (> n 5))
(define (big l)
  (filter-nums more-than-5 l))

(define (more-than-10 n)
  (> n 10))
(define (huge l)
  (filter-nums more-than-10 l))
```

Big and Huge Fish, Again

```
(define (more-than-5 n)
  (> n 5))
(define (big l)
  (filter-nums more-than-5 l))

(define (more-than-10 n)
  (> n 10))
(define (huge l)
  (filter-nums more-than-10 l))
```

The `more-than-5` and `more-than-10` functions are really only useful to `big` and `huge`

We could make them `local` to clarify...

Big and Huge Fish, Improved

```
(define (big l)
  (local [(define (more-than-5 n)
             (> n 5))]
    (filter-nums more-than-5 l)))
```

```
(define (huge l)
  (local [(define (more-than-10 n)
             (> n 10))]
    (filter-nums more-than-10 l)))
```

Big and Huge Fish, Improved

```
(define (big l)
  (local [(define (more-than-5 n)
             (> n 5))]
    (filter-nums more-than-5 l)))
```

```
(define (huge l)
  (local [(define (more-than-10 n)
             (> n 10))]
    (filter-nums more-than-10 l)))
```

Cut and paste alert!

You don't think I typed that twice, do you?

Big and Huge Fish, Generalized

```
(define (bigger-than l m)
  (local [(define (more-than-m n)
             (> n m))]
    (filter-nums more-than-m l)))

(define (big l) (bigger-than l 5))
(define (huge l) (bigger-than l 10))
```

Big Example

...

```
(define (bigger-than l m)
  (local [(define (more-than-m n)
             (> n m))]
    (filter-nums more-than-m l)))
(define (big l) (bigger-than l 5)) ...
(big '(7 4 9))
(huge '(7 4 9))
```

Big Example

```
...
(define (bigger-than l m)
  (local [(define (more-than-m n)
             (> n m))]
    (filter-nums more-than-m l)))
(define (big l) (bigger-than l 5)) ...
(big '(7 4 9))
(huge '(7 4 9))
```

→

```
...
(define (bigger-than l m)
  (local [(define (more-than-m n)
             (> n m))]
    (filter-nums more-than-m l)))
...
(bigger-than '(7 4 9) 5)
(huge '(7 4 9))
```

Big Example

...

```
(define (bigger-than l m)
  (local [(define (more-than-m n)
             (> n m))]
    (filter-nums more-than-m l)))
```

...

```
(bigger-than '(7 4 9) 5)
(huge '(7 4 9))
```


Big Example

...

```
(define (bigger-than l m)
  (local [(define (more-than-m n)
             (> n m))]
    (filter-nums more-than-m l)))
```

...

```
(bigger-than '(7 4 9) 5)
(huge '(7 4 9))
```

→

...

```
(local [(define (more-than-m n)
             (> n 5))]
  (filter-nums more-than-m '(7 4 9)))
(huge '(7 4 9))
```

Big Example

...

```
(local [(define (more-than-m n)
          (> n 5))]
  (filter-nums more-than-m '(7 4 9)))
(huge '(7 4 9))
```

Big Example

...

```
(local [(define (more-than-m n)
          (> n 5))]
  (filter-nums more-than-m '(7 4 9)))
(huge '(7 4 9))
```

→

...

```
(define (more-than-m42 n)
  (> n 5))
(filter-nums more-than-m42 '(7 4 9))
(huge '(7 4 9))
```

Big Example

...

```
(define (more-than-m42 n)
  (> n 5))
(filter-nums more-than-m42 '(7 4 9))
(huge '(7 4 9))
```

Big Example

...

```
(define (more-than-m42 n)
  (> n 5))
(filter-nums more-than-m42 '(7 4 9))
(huge '(7 4 9))
```

→

...

```
(define (more-than-m42 n)
  (> n 5))
'(7 9)
(huge '(7 4 9))
```

after many steps

Big Example

...

```
(define (more-than-m42 n)
```

```
  (> n 5))
```

```
'(7 9)
```

```
(huge '(7 4 9))
```

Big Example

...

```
(define (more-than-m42 n)
  (> n 5))
'(7 9)
(huge '(7 4 9))
```

→

...

```
(define (bigger-than l m)
  (local [(define (more-than-m n)
              (> n m))]
    (filter-nums more-than-m l)))
```

...

```
(define (more-than-m42 n)
  (> n 5))
'(7 9)
(bigger-than '(7 4 9) 10)
```

Big Example

...

```
(define (bigger-than l m)
  (local [(define (more-than-m n)
             (> n m))]
    (filter-nums more-than-m l)))
```

...

```
(define (more-than-m42 n)
  (> n 5))
'(7 9)
(bigger-than '(7 4 9) 10)
```


Big Example

...

```
(define (bigger-than l m)
  (local [(define (more-than-m n)
            (> n m))]
    (filter-nums more-than-m l)))
```

...

```
(define (more-than-m42 n)
  (> n 5))
'(7 9)
(bigger-than '(7 4 9) 10)
```

→

...

```
(define (more-than-m42 n)
  (> n 5))
'(7 9)
(local [(define (more-than-m n)
          (> n 10))]
  (filter-nums more-than-m '(7 4 9)))
```

Big Example

...

```
(define (more-than-m42 n)
  (> n 5))
'(7 9)
(local [(define (more-than-m n)
            (> n 10))]
  (filter-nums more-than-m '(7 4 9)))
```

Big Example

```
...  
(define (more-than-m42 n)  
  (> n 5))  
'(7 9)  
(local [(define (more-than-m n)  
          (> n 10))]  
  (filter-nums more-than-m '(7 4 9)))
```

→

```
...  
(define (more-than-m42 n)  
  (> n 5))  
'(7 9)  
(define (more-than-m79 n)  
  (> n 10))  
(filter-nums more-than-m79 '(7 4 9))
```

Etc.

Abstraction

- Avoiding cut and paste is ***abstraction***
- No real programming task succeeds without it