

# CS1102: Macros and Recursion

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This lecture looks at several more macro examples. It aims to show you when you can use recursion safely with macros and when you can't.

## 1 Multi-Argument Or

We talked about how to define **or** as a macro, and why it needed to be defined as a macro instead of as a function. As a reminder, we developed the following macro for **or** (calling it **myor** to avoid a name clash within Scheme):

```
(define-syntax myor
  (syntax-rules ()
    [(myor e1 e2) (cond [e1 true]
                        [else e2])]))
```

This macro limited **or** to two arguments. The real **or** macro in Scheme accepts arbitrary numbers of arguments. Here are some examples:

```
> (or (= 3 2))
false
```

```
> (or (= 3 4) (> 6 9) (< 2 7))
true
```

Let's change **myor** to accept an arbitrary number of arguments. How might we write that? First, we need to change the input pattern to expect an arbitrary number of arguments. Then, if *e1* isn't true, check **myor** on the rest of the inputs:

```
(define-syntax myor
  (syntax-rules ()
    [(myor e1 ...)
     (cond [e1 true]
           [else (myor ...)])]))
```

Scheme rejects this with an error saying "syntax: missing ellipses with pattern variable in template in: e1". The problem is in the else clause: you can't have ... without the variable that goes with it

being nearby. We don't want to insert *e1* into the **myor** in the else clause, so we need to introduce a second pattern variable:

```
(define-syntax myor
  (syntax-rules ()
    [(myor e1 e2 ...)
     (cond [e1 true]
           [else (myor e2 ...)])]))
```

Trying this on input (**myor** (= 2 2) (> 3 4)) yields an error “myor: bad syntax in: (myor)”. What happened? Let's look at the sequence of expansions that Scheme performs to expand uses of **myor** according to the pattern:

```
(myor (= 2 2) (> 3 4))
= (cond [(= 2 2) true]
        [else (myor (> 3 4))])
= (cond [(= 2 2) true]
        [else (cond [(> 3 4) true]
                    [else (myor)])])
= error
```

Notice that the second else clause needs to expand (**myor**), but the input pattern requires at least one argument (*e1*). To handle this, add another pattern to the macro that defines **myor** with no arguments.

then we need to adjust the output pattern. How about the following?

```
(define-syntax myor
  (syntax-rules ()
    [(myor) false]
    [(myor e1 e2 ...)
     (cond [e1 true]
           [else (myor e2 ...)])]))
```

The first pattern is like the base case in a recursive function – it gives a concrete answer on a specific number of arguments. The second is the recursive case. As in the recursions we've written before, we reduce the number of arguments on the recursive call.

## 2 Real For-loops

A friend is fed-up with the lack of for and while loops in Scheme and decides to implement his own for-loop construct. As an example, your friend wants to be able to type

```
(for i 0 5 (printf "~a " i))
```

and have Scheme produce

```
0 1 2 3 4 5
```

(with *void* returned as the result of the expression).

Should you implement **for** as a function or a macro? Why?

**For** looks like a macro because of the expression you want to iterate over. If you implement **for** as a function, you'll run the *printf* when you call **for**, and you'll get an unbound identifier error because you have no value for *i*. With that in mind, write a macro for **for**.

**(define-syntax for**

**(syntax-rules ()**

```
  [(for var low high expr)
   (local [(define (loop var)
             (cond [(> var high) void]
                   [else (begin expr
                                (loop (+ 1 var)))]))]
     (loop low)))]
```

Notice that this for-loop does not use assignment (as you are accustomed to using with for-loops). There's no need to assign an index variable – you can just use recursion. Isn't this limiting though, because the macro fixes how much to increase *i* by each time? We could relax that by adding another pattern to the macro that supplies that information:

**(define-syntax for**

**(syntax-rules ()**

```
  [(for var low high expr)
   (local [(define (loop var)
             (cond [(> var high) void]
                   [else (begin expr
                                (loop (+ 1 var)))]))]
     (loop low))]
  [(for var low high expr incr)
   (local [(define (loop var)
             (cond [(> var high) void]
                   [else (begin expr
                                (loop (+ var incr)))]))]
     (loop low)))]
```

Note that this macro duplicates a lot of code across the two cases. We can fix that by converting the case with no increment supplied into the case with an increment supplied.

**(define-syntax for**

**(syntax-rules ()**

```
  [(for var low high expr)
   (for var low high expr 1)]
  [(for var low high expr incr)
```

```
(local [(define (loop var)
         (cond [(> var high) void]
               [else (begin expr
                            (loop (+ var incr)))]))]
        (loop low)))]
```

But wait! This looks recursive, like what we had tried for the multi-armed `or`. Why does this one work, when the recursive `or` did not? This macro isn't recursive. The first version rewrites into the second *one time only*. The recursion is in the loop function, which does not use `for` again. In the case of `or`, the recursion invoked the macro itself; that created the infinite loop.

As an aside, you may have wondered why we didn't try to break up the `for` macro into two cases as we did for the multi-armed `or`. For that, you might have tried the following:

```
(define-syntax for
  (syntax-rules ()
    [(for var low var expr) expr]
    [(for var low high expr)
     (begin expr (for var low (+ 1 var)))]))
```

This isn't a valid macro, since the first cases tries to use `var` twice and Scheme doesn't support that. You can't split up these cases in this manner.

### 3 Map

Since we've written a recursive macro for `or`, why don't we write one for `map`? How about this?

```
(define-syntax mymap
  (syntax-rules ()
    [(mymap func lst)
     (cond [(empty? lst) empty]
           [(cons? lst)
            (cons (func (first lst))
                  (mymap func (rest lst)))])))]
```

If we test this macro, we find we go into an infinite loop. Why? Recursion worked for `or`, so why doesn't it work for `map`?

There's a big difference between the two macros. With `myor`, notice that the recursion has a base case *as one of the patterns in the macro*. In `mymap`, there's only one case. Macro-expansion works by replacing every use of a macro with its output pattern until no more uses of macros remain. Furthermore, since macro-expansion takes place without evaluating expressions (the whole point of having them!), there's no way to hit a base case within the expanded code. In other words, macro-expansion of a call to `mymap` proceeds in several steps, ad infinitum:

```
(mymap square (list 1 2 3))
= (cond [(empty? (list 1 2 3)) empty]
```

```

[(cons? (list 1 2 3))
 (cons (square (first (list 1 2 3)))
       (mymap square (rest (list 1 2 3)))))]
= (cond [(empty? (list 1 2 3)) empty]
        [(cons? (list 1 2 3))
         (cons (square (first (list 1 2 3)))
               (cond [(empty? (rest (list 1 2 3))) empty]
                     [(cons? (rest (list 1 2 3)))
                      (cons (square (first (rest (list 1 2 3))))
                            (mymap square (rest (rest (list 1 2 3))))))]))])
= ...

```

Without evaluating the lists, there's no way to stop the expansion, hence the infinite loop.

## 4 Summary

Macros can be recursive, but the base case must be one of the (multiple) patterns, not buried *within* one of the output patterns. This is necessary for macro expansion to terminate.