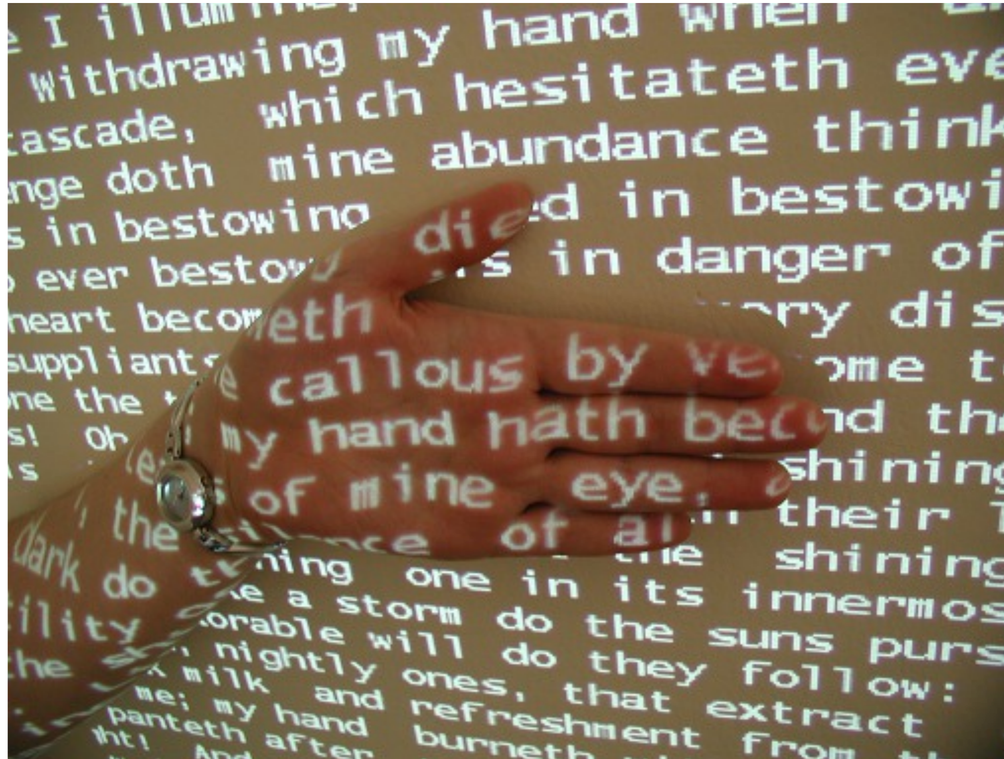
Keeping it Clean with Syntax Parameters



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Macros

Macros are great.

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Hygienic macros are great.

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(define-struct point (x y))
(point-x (make-point 1 2))
```

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(define-struct point (x y))
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```

➡ `(datum->syntax name a-symbol)`

Macros

Hygienic macros are great, but...

```
(define-syntax forever
  (syntax-rules ()
    [(forever body ...)
     (call/cc (lambda (abort)
                (let loop ()
                  body ... (loop))))]))
```

Macros

Hygienic macros are great, but...

```
(define-syntax aif
  (syntax-rules ()
    [(aif test then else)
     (let ([it test])
       (if it then else))]))
```

Non-Solution#1

```
(define-syntax (forever stx)
  (syntax-case stx ()
    [(forever body ...)
     (with-syntax ([abort (datum->syntax
                              #'forever 'abort)])
       #'(call/cc (lambda (abort)
                    (let loop ()
                      body ... (loop))))))]))
```

Non-Solution#1

```
(define-syntax (forever stx)
  (syntax-case stx ()
    [(forever body ...)
     (with-syntax ([abort (datum->syntax
                           #'forever 'abort)])
       #'(call/cc (lambda (abort)
                    (let loop ()
                      body ... (loop)))))]))

(define-syntax while
  (syntax-rules ()
    [(while test body ...)
     (forever (unless test (abort)) body ...)]))
```

Non-Solution#1

```
(define-syntax (forever stx)
  (syntax-case stx ()
    [(forever body ...)
     (with-syntax ([abort (datum->syntax
                            #'forever 'abort)])
       #'(call/cc (lambda (abort)
                    (let loop ()
                      body ... (loop)))))]))

(define-syntax while
  (syntax-rules ()
    [(while test body ...)
     (forever (unless test (abort)) body ...)]))
```

```
> (while #t (abort))
```

Non-Solution#1

```
(define-syntax (forever stx)
  (syntax-case stx ()
    [(forever body ...)
     (with-syntax ([abort (datum->syntax
                           #'forever 'abort)])
       #'(call/cc (lambda (abort)
                    (let loop ()
                      body ... (loop)))))]))

(define-syntax while
  (syntax-rules ()
    [(while test body ...)
     (forever (unless test (abort)) body ...)]))
```

```
> (while #t (abort))
```

reference to undefined identifier: abort

Non-Solution#1

```
(define-syntax (forever stx)
  (syntax-case stx ()
    [(forever body ...)
     (with-syntax ([abort (datum->syntax
                            #'forever 'abort)])
       #'(call/cc (lambda (abort)
                    (let loop ()
                      body ... (loop)))))]))

(define-syntax (while stx)
  (syntax-case stx ()
    [(while test body ...)
     (with-syntax ([forever (datum->syntax
                              #'while 'forever)])
       #'(forever (unless test (abort))
                  body ...))]))
```

Non-Solution#1

```
(define-syntax (forever stx)
  (syntax-case stx ()
    [(forever body ...)
     (with-syntax ([abort (datum->syntax
                            #'forever 'abort)])
       #'(call/cc (lambda (abort)
                    (let loop ()
                      body ... (loop)))))]))

(define-syntax (while stx)
  (syntax-case stx ()
    [(while test body ...)
     (with-syntax ([forever (datum->syntax
                              #'while 'forever)])
       #'(forever (unless test (abort))
                  body ...))]))
```

Non Solution #2

“Hygiene macros are ok, but for **real** code, use **`defmacro`**”

Fix Solution #1

```
(define-syntax (while stx)
  (syntax-case stx ()
    [(while test body ...)
     #'(forever (unless test (abort))
                body ...)]))
```

Fix Solution #1

```
(define-syntax (while stx)
  (syntax-case stx ()
    [(while test body ...)
     (with-syntax (; abort* is user-accessible as `abort'
                   [abort* (datum->syntax
                             #'while 'abort)])
       #'(forever (let (; link the two bindings
                        [abort* abort])
                   (unless test (abort))
                   body ...)))]))
```

Fix Solution #1

```
(define-syntax (while stx)
  (syntax-case stx ()
    [(while test body ...)
     (with-syntax (; abort* is user-accessible as `abort'
                   [abort* (datum->syntax
                            #'while 'abort)])
       #'(forever (let (; link the two bindings
                        [abort* abort])
                   (unless test (abort))
                   body ...)))]))

     (define-syntax (until stx)
       (syntax-case stx ()
         [(until test body ...)
          (with-syntax ([abort* (datum->syntax
                                 #'until 'abort)])
            #'(while (not test)
                (let ([abort* abort]) body ...)))]))
```

Fix Solution #1

```
(define-syntax (while stx)
  (syntax-case stx ()
    [(while test body ...)
     (with-syntax (; abort* is user-accessible as `abort'
                   [abort* (datum->syntax
                            #'while 'abort)])
       #'(forever (let (; link the two bindings
                        [abort* abort])
                    (unless test (abort))
                    body ...)))]))

(define-syntax (until stx)
  (syntax-case stx ()
    [(until test body ...)
     (with-syntax ([abort* (datum->syntax
                            #'until 'abort)])
       #'(while (not test)
           (let ([abort* abort]) body ...)))]))
```

- What if **abort** is a macro binding?
- Not mechanical enough to automate

Fix Solution #1

```
(define-syntax (while stx)
  (syntax-case stx ()
    [(while test body ...)
     (with-syntax (; abort* is user-accessible as `abort'
                   [abort* (datum->syntax
                            #'while 'abort)])
       #'(forever (let (; link the two bindings
                          [abort* abort])
                    (unless test (abort))
                    body ...)))]))

     (define-syntax (until stx)
       (syntax-case stx ()
         [(until test body ...)
          (with-syntax ([abort* (datum->syntax
                                 #'until 'abort)])
            #'(while (not test)
                (let ([abort* abort]) body ...)))]))
```

- `(make-rename-transformer #'abort)`
- Specify "link point"

Automated Solution

Define a **define-syntax-rules/capture** macro to automate linking. "Link points" specified with an **L**.

```
(define-syntax-rules/capture forever (abort) ()
  [(forever body ...)
   (call/cc (lambda (abort)
              (L (let loop () body ... (loop)))))])

(define-syntax-rules/capture while (abort) ()
  [(while test body ...)
   (forever (L (unless test (abort)) body ...))])

(define-syntax-rules/capture until (abort) ()
  [(until test body ...)
   (while (L (not test)) (L body ...))])
```

- We can even use the same macro to define the base level **forever** macro.

Automated Solution

Define a **define-syntax-rules/capture** macro to automate linking. "Link points" specified with an **L**.

```
(define-syntax-rules/capture forever (abort) ()
  [(forever body ...)
   (call/cc (lambda (abort)
              (L (let loop () body ... (loop)))))])

(define-syntax-rules/capture while (abort) ()
  [(while test body ...)
   (forever (L (unless test (abort)) body ...))])

(define-syntax-rules/capture until (abort) ()
  [(until test body ...)
   (while (L (not test)) (L body ...))])
```

```
(define-syntax until
  (syntax-rules ()
    [(until test body ...)
     (while (not test) body ...)]))
```

Automated Solution

Define a **`define-syntax-rules/capture`** macro to automate linking. "Link points" specified with an **`L`**.

```
(define-syntax-rules/capture forever (abort) ()
  [(forever body ...)
   (call/cc (lambda (abort)
              (L (let loop () body ... (loop)))))])

(define-syntax-rules/capture while (abort) ()
  [(while test body ...)
   (forever (L (unless test (abort)) body ...))])

(define-syntax-rules/capture until (abort) ()
  [(until test body ...)
   (while (L (not test)) (L body ...))])
```

```
(define-syntax until
  (syntax-rules ()
    [(until test body ...)
     (while (not test) body ...)]))
```

does not propagate the **`abort`** binding.

The “Simple” Utility

```
(define-syntax (define-syntax-rules/capture stx0)
  (syntax-case stx0 ()
    [(def name (capture ...) (keyword ...) [patt templ] ...)
     (with-syntax ([L (datum->syntax #'def 'L)])
       #'(define-syntax (name stx)
           (syntax-case stx (keyword ...)
             [patt (with-syntax ([user-ctx stx])
                     #'(with-links L user-ctx (capture ...) templ))]
             ...))))]))

(define-syntax with-links
  (syntax-rules ()
    [(with-links L user-ctx (capture ...) template)
     (let-syntax
         ([L (lambda (stx)
               (syntax-case stx ()
                 [(L e (... ...))
                  (with-syntax ([(id  (... ...)) (list (datum->syntax #'L 'capture) ...)]
                                [(id* (... ...)) (list (syntax-local-introduce
                                                         (datum->syntax #'user-ctx 'capture))
                                                        ...)])
                    #'(let-syntax ([id* (make-rename-transformer #'id)]
                                   (... ...))
                        e (... ...)))]))])
       template)]))
```

Works But...

- Tedious to propagate unhygienically-bound names around
- Might not be possible with library macros that we didn't write

➡ Same kind of problems that lead to **`fluid-let`**.

Non Solution #3

“Never break hygiene!” — always specify bindings.

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```
(define-syntax forever
  (syntax-rules ()
    [(forever abort body ...)
     (call/cc (lambda (abort)
                (let loop () body ... (loop))))]))
```

Non Solution #3

“Never break hygiene!” — always specify bindings.

```
(define-syntax forever
  (syntax-rules ()
    [(forever abort body ...)
     (call/cc (lambda (abort)
                (let loop () body ... (loop))))]))

(define-syntax aif
  (syntax-rules ()
    [(aif it test then else)
     (let ([it test]) (if it then else))]))
```

Non Solution #3

“Never break hygiene!” — always specify bindings.

```
(define-syntax forever
  (syntax-rules ()
    [(forever abort body ...)
     (call/cc (lambda (abort)
                (let loop () body ... (loop))))]))

    (define-syntax aif
      (syntax-rules ()
        [(aif it test then else)
         (let ([it test]) (if it then else))]))

 (define-syntax while
   (syntax-rules ()
     [(while abort it test body ...)
      (forever abort
        (aif it test (begin body ...) (abort)))]))
```

Non Solution #3

But this is worse...

```
(while abort it (memq x l)
  (display (car it))
  (set! l (cdr it)))
```

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```
(while abort it (memq x l)
  (display (car it))
  (set! l (cdr it)))
```

```
(define-syntax until
  (syntax-rules ()
    [(until abort it test body ...)
     (while abort it (not test) body ...)]))
```

Non Solution #3

But this is worse...

```
(while abort it (memq x l)
  (display (car it))
  (set! l (cdr it)))
```

```
(define-syntax until
  (syntax-rules ()
    [(until abort it test body ...)
     (while abort it (not test) body ...)]))
```

(Even worse with core language constructs.)

Solution: Dynamic Bindings

In the runtime world, we avoid threading parameters along call-chains using “dynamic bindings”.

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```
(define (abort)
  (error "abort must be used in a loop"))
(define (thunk-forever body-thunk)
  (call/cc
   (lambda (k)
     (fluid-let ([abort k])
       (let loop () (body-thunk) (loop))))))
(thunk-forever
 (lambda ()
   (let ([c (read-char)])
     (if (eof-object? c)
         (abort)
         (display (char-upcase c))))))
```

Solution: Dynamic Bindings

In the runtime world, we avoid threading parameters along call-chains using "dynamic bindings".

```
(define (abort)
  (error "abort must be used in a loop"))
(define (thunk-forever body-thunk)
  (call/cc
   (lambda (k)
     (fluid-let ([abort k])
       (let loop () (body-thunk) (loop))))))
(thunk-forever
 (lambda ()
   (let ([c (read-char)])
     (if (eof-object? c)
         (abort)
         (display (char-upcase c))))))
```

- The binding is lexical, the value is dynamically adjusted

Solution: Parameters

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  Parameters: avoid indiscriminate use.

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- **`fluid-let`** is too strong: `(fluid-let ([cons +]) ...)`

Parameters: avoid indiscriminate use.

```
(define current-abort
  (make-parameter
   (lambda () (error "abort must be used in a loop"))))

(define (abort) ((current-abort)))

(define (thunk-forever body-thunk)
  (call/cc
   (lambda (k)
     (parameterize ([current-abort k])
       (let loop () (body-thunk) (loop))))))
```

Solution: Parameters

- **fluid-let** is too strong: `(fluid-let ([cons +]) ...)`

Parameters: avoid indiscriminate use.

```
(define current-abort
  (make-parameter
   (lambda () (error "abort must be used in a loop"))))

(define (abort) ((current-abort)))

(define (thunk-forever body-thunk)
  (call/cc
   (lambda (k)
     (parameterize ([current-abort k])
       (let loop () (body-thunk) (loop))))))
```

- **abort** also separates ‘read’ and ‘write’ access

Syntax Parameters

The same solution of an adjustable binding carries over to the syntax world.

- ➨ Prefer **`syntax-parameterize`** over **`fluid-let-syntax`** for similar reasons.

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The same solution of an adjustable binding carries over to the syntax world.

- Prefer **`syntax-parameterize`** over **`fluid-let-syntax`** for similar reasons.

```
(define-syntax-parameter abort
  (syntax-rules ()))

(define-syntax forever
  (syntax-rules ()
    [(forever body ...)
     (call/cc
      (lambda (abort-k)
        (syntax-parameterize
            ([abort
              ; or `make-rename-transformer'
              (syntax-rules () [(_) (abort-k)])])
          (let loop () body ... (loop)))))]))
```

Syntax Parameters

The same solution of an adjustable binding carries over to the syntax world.

➡ Prefer **syntax-parameterize** over **fluid-let-syntax** for similar reasons.

```
(define-syntax-parameter abort
  (syntax-rules ()))

(define-syntax forever
  (syntax-rules ()
    [(forever body ...)
     (call/cc
      (lambda (abort-k)
        (syntax-parameterize
            ([abort
              ; or `make-rename-transformer'
              (syntax-rules () [(_) (abort-k)])])
          (let loop () body ... (loop)))))]))
```

Everything “just works” now.

Conclusions

- Very convenient
- Modular macros, abstract both macros and on syntax parameters (eg, a macro that abstracts over **`abort`**)
- Used extensively in Racket
- Like **`syntax-rules`** — covers many more cases, but there are still uses for unhygienic macros

Subtleties I

```
; Two seemingly identical abstractions
(define a (lambda () (abort)))
(define-syntax a (syntax-rules () [(_) (abort)]))

> (forever
    (define a (lambda () (abort)))
    (forever (display "inner\n") (a))
    (display "outer\n")
    (abort))
inner

> (forever
    (define-syntax a (syntax-rules () [(_) (abort)]))
    (forever (display "inner\n") (a))
    (display "outer\n")
    (abort))
inner
outer
```

Subtleties II

```
(define-syntax ten-times
  (syntax-rules ()
    [(_ body ...)
     (let loop ([n 10])
       (when (> n 0) body ... (loop (- n 1))))]))

; Refactor
(define-syntax ten-times
  (syntax-rules ()
    [(_ body ...)
     (let ([n 10])
       (forever body ...
                (set! n (- n 1))
                (when (= n 0) (abort))))]))

> (forever (ten-times (display "hey\n") (abort)))
; loops forever
```

Subtleties II

```
(define-syntax (ten-times stx)
  (syntax-case stx ()
    [(_ body ...)
     (with-syntax ([old (syntax-parameter-value #'abort)])
       #'(let ([n 10])
           (forever (syntax-parameterize ([abort old]) body ...)
                    (set! n (- n 1))
                    (when (= n 0) (abort)))))]))
```

Conclusions II

- Very convenient
- Modular macros, abstract both macros and on syntax parameters (eg, a macro that abstracts over **`abort`**)
- Used extensively in Racket
- Like **`syntax-rules`** — covers many more cases, but there are still uses for unhygienic macros
- Need to be aware of subtleties, but still better for newbies, and easy to get an intuition for experienced macro writers.