Macros
User-Extensible Syntax

slides adapted from Dan Grossman

A macro is user-defined syntactic sugar.

- A ***macro definition*** describes how to transform some new syntax into different syntax in the source language
- A ***macro system*** is a language (or part of a larger language) for defining macros
- ***Macro expansion*** is the process of rewriting the syntax for each ***macro use***
  - **Before a program is run (or even compiled)**

Example Racket Macros

Definitions:
- Expand `(my-if e1 then e2 else e3)` to `(if e1 e2 e3)`
- Expand `(comment-out e1 e2)` to `e2`

It is like we added keywords to our language
- Other keywords only keywords in uses of that macro
- Syntax error if keywords misused
- Rewriting ("expansion") happens before execution

Uses:

```
(my-if x then y else z)   ; (if x y z)
(my-if x then y then z)   ; syntax error

(comment-out (car null) #f)
```

Overuse

Macros sometimes get a bad wrap for being overused.

Rule of thumb:
Use macros only where functions would be awkward or impossible.

They can be useful!

Tokenization

First question for a macro system: How does it tokenize?

- Macro systems generally work at the level of *tokens* not sequences of characters
  - So must know how programming language tokenizes text
- Example: "macro expand **`head`** to **`car`**"
  - Would not rewrite **`(+ headt foo)`** to **`(+ cart foo)`**
  - Would not rewrite **`head-door`** to **`car-door`**
    - But would in C where **`head-door`** is subtraction

Parenthesization

Second question for a macro system: How does associativity work?

C/C++ preprocessor basic example:

```
#define ADD(x,y) x+y
```

Probably *not* what you wanted:

`ADD(1,2/3)*4` means `1 + 2 / 3 * 4` not `(1 + 2 / 3) * 4`

"Solution": emphatic parenthesization

```
#define ADD(x,y) ((x)+(y))
```

Racket won't have this problem:

- Macro use: **`(macro-name …)`**
- After expansion: **`( *something else in same parens* )`**

Local bindings

Third question for a macro system: Can variables shadow macros?

Suppose macros also apply to variable bindings. Then:

```
(let  ([head 0][car 1]) head) ; 0
(let* ([head 0][car 1]) head) ; 0
```

Would become:

```
(let  ([car 0][car 1]) car) ; error
(let* ([car 0][car 1]) car) ; 1
```

C/C++ convention: all-caps macros and non-all-caps everything else

Racket does *not* work this way – it gets scope "right"!

Example Racket macro definitions

Two simple macros

```
(define-syntax my-if              ; macro name
  (syntax-rules (then else)       ; other keywords
    [(my-if e1 then e2 else e3)   ; macro use
     (if e1 e2 e3)]))             ; form of expansion
```

```
(define-syntax comment-out        ; macro name
  (syntax-rules ()                ; other keywords
    [(comment-out ignore instead) ; macro use
     instead]))         ; form of expansion
```

If the form of the use matches, do the corresponding expansion

- In these examples, list of possible use forms has length 1
- Else syntax error

A bad macro

Any *function* that doubles its argument is fine for clients

```
(define (dbl x) (+ x x))
(define (dbl x) (* 2 x))
```

- These are equivalent to each other

So macros for doubling are bad style but instructive examples:

```
(define-syntax dbl (syntax-rules()[(dbl x)(+ x x)]))
(define-syntax dbl (syntax-rules()[(dbl x)(* 2 x)]))
```

- These are not equivalent to each other. Consider:

```
(dbl (begin (print "hi") 42))
```

More examples

Sometimes a macro *should* re-evaluate an argument it is passed
- If not, as in **dbl**, then use a local binding as needed:

```
(define-syntax dbl
  (syntax-rules ()
    [(dbl x)
     (let ([y x]) (+ y y))]))
```

Also good style for macros not to have surprising evaluation order
- Good rule of thumb to preserve left-to-right
- Bad example (fix with a local binding):

```
(define-syntax take
  (syntax-rules (from)
    [(take e1 from e2)
     (- e2 e1)]))
```

Local variables in macros

In C/C++, defining local variables inside macros is unwise
- When needed done with hacks like **__strange_name34**

Silly example:
- Macro:

```
(define-syntax dbl
  (syntax-rules ()
    [(dbl x) (let ([y 1])
               (* 2 x y))]))
```

- Use:

```
(let ([y 7]) (dbl y))
```

- Naïve expansion:

```
(let ([y 7]) (let ([y 1])
               (* 2 y y)))
```

- But instead Racket "gets it right," which is part of *hygiene*

The other side of hygiene

This also looks like it would do the "wrong" thing

- Macro:

```
(define-syntax dbl
  (syntax-rules ()
    [(dbl x) (* 2 x)]))
```

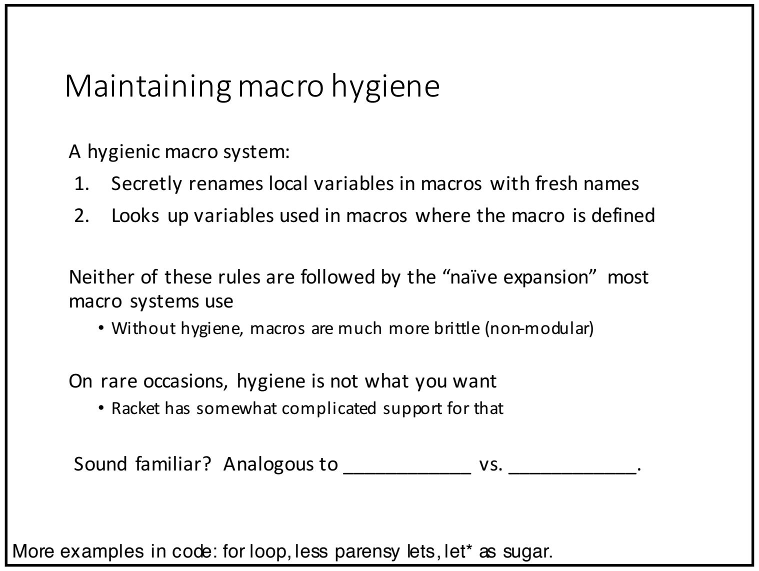
- Use:

```
(let ([* +]) (dbl 42))
```

- Naïve expansion:

```
(let ([* +]) (* 2 42))
```

- But again Racket's *hygienic macros* get this right!



Maintaining macro hygiene

A hygienic macro system:

1. Secretly renames local variables in macros with fresh names
2. Looks up variables used in macros where the macro is defined

Neither of these rules are followed by the "naïve expansion" most macro systems use

- Without hygiene, macros are much more brittle (non-modular)

On rare occasions, hygiene is not what you want

- Racket has somewhat complicated support for that

Sound familiar? Analogous to ____________ vs. ____________.

More examples in code: for loop, less parensy lets, let* as sugar.