What is a macro

- A macro definition describes how to transform some new syntax into different syntax in the source language.
- A macro is one way to implement syntactic sugar:
  - “Replace any syntax of the form `e1 andalso e2 with if e1 then e2 else false’.”
- 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).

Using Racket Macros

- If you define a macro `m` in Racket, then `m` becomes a new special form:
  - Use `(m …)` gets expanded according to definition.
- Example definitions (actual definitions coming later):
  - Expand `(my-if e1 then e2 else e3)` to `(if e1 e2 e3)`.
  - Expand `(comment-out e1 e2)` to `e2`.
  - Expand `(my-delay e)` to `(mcons #f (lambda () e))`.

Example uses

It is like we added keywords to our language:
- Other keywords only apply in uses of that macro.
- Syntax error if keywords are used elsewhere.
- Rewriting (“expansion”) happens before execution.

```
(my-if x then y else z) ; (if x y z)
(my-if x then y then z) ; syntax error
(comment-out (car null) #fl) ; syntax error
(my-delay (begin (print "hi") (foo 15)))
```

Overuse

Macros often deserve a bad reputation because they are often overused or used when functions would be better.

When in doubt, resist defining a macro?
But they can be used well.

Now...

- How any macro system must deal with tokens, parentheses, and scope.
- How to define macros in Racket.
- How macro definitions must deal with expression evaluation carefully:
  - Order expressions evaluate and how many times.
- The key issue of variable bindings in macros and the notion of hygiene:
  - Racket is superior to most languages here.
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 (+ head 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++ basic example:

```c
#define ADD(x, y) x+y
ADD(1, 2/3)*4
```

```c
1 + 2/3 * 4
```

```c
(1 + 2/3) * 4
```

Racket does not have this problem:

```racket
(macro-use: (macro-name \(\ldots\))
   \(\text{after expansion: something else in same place}\))
```

Local bindings

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

Suppose macros also apply to variable bindings. Then:

C/C++ convention is all-caps macros and non-all-caps for everything else.

Racket does not work this way – it gets scope “right”.

Example Racket macro definitions

Two simple macros:

```racket
(define-syntax my-if
   (syntax-rules ()
     \([\text{my-if } e \text{ then } e_2 \text{ else } e_3\])
     \(\text{if } e_{1} e_{2} e_{3}\))
)(f (my-delay e))
```

Revisiting delay and force

Recall our definition of promises from earlier.

- Should we use a macro instead to avoid clients’ explicit thunk?

```racket
(define-syntax my-delay
   (syntax-rules ()
     \([\text{my-delay } e]\)
     \(\text{mcons } \#f \text{ (lambda } () e)\))

(define my-force p)
\(\text{if } (\text{mcar p}) \text{ (mcdr p)}\)
\(\text{set-mcadr! } p \text{ ((mcdr p))}\)
\(\text{mcdr p})\)

(f (my-delay \(\lambda e\)))
(define (f p)
\(\text{(my-force p \ldots})\))
```

A delay macro

- A macro can put an expression under a thunk
- Delays evaluation without explicit thunk
- Cannot implement this with a function
- Now client should not use a thunk (that would double-thunk)
- Racket’s pre-defined delay is a similar macro:

```racket
(define-syntax my-delay
   (syntax-rules ()
     \([\text{my-delay } e]\)
     \(\text{mcons } \#f \text{ (lambda } () e)\))

(f (my-delay e))
```
What about a force macro?

We could define `my-force` with a macro too.
- Good macro style would be to evaluate the argument exactly once (use `x` below, not multiple evaluations of `e`).
- Do not use macros when functions do what you want.

```
(define-syntax my-force
  (syntax-rules ()
    [(my-force e)
      (let ([x e])
        (if (mcar x)
            (mcdr x)
            (begin
              (set-mcar! x #t)
              (set-mcdr! p ((mcdr p)))
              (mcdr p))))]))
```

Another bad macro

Any function that doubles its argument is fine for clients.
- These are equivalent to each other.

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

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

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

```
(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) (* 2 x)]))
```

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

```
(let ([y 7] [* +]) (* 2 42))
```

Local variables in macros

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

Here is why with a 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) (let ([y 1]) (* 2 x y))]))
```
- Use:
```
(let ([y 7]) (dbl 42))
```
- Naïve expansion:
```
(let ([y 7]) (* 2 42))
```
- But again Racket's hygienic macros get this right.

How hygienic macros work

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.
More examples

See the code for macros that:

- A for loop for executing a body a fixed number of times
  - Shows a macro that purposely re-evaluates some expressions and not others

- Allow 0, 1, or 2 local bindings with fewer parens than let*
  - Shows a macro with multiple cases

- A re-implementation of let* in terms of let
  - Shows a macro taking any number of arguments
  - Shows a recursive macro