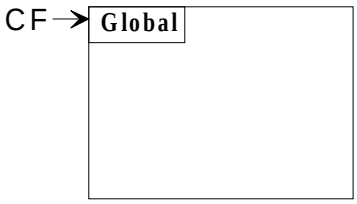
Given that the following were evaluated sequentially, draw the corresponding environment diagram.

```
> (define (quiz-cons a b)
     (let ((cons (cons (a b))))
        (lambda (mesg)
           (define wasted 6)
           (cond ((eq? 'bark mesg) b)
                 ((eq? 'woof mesg) a)
                 ((eq? 'cons mesg) cons)
                 (else (error "ERR" mesg))) )))
> (define apple (quiz-cons 'apple 'core))
> (define no-apple (quiz-cons 'apple "Oh! There's more!"))
> (cdr (no-apple 'cons))
> (define ghastly (cons (apple 'bark) (no-apple 'woof)))
> (set-car! ghastly apple)
```

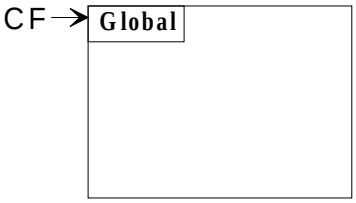
Evaluating: (define (quiz-cons a b) ...)



This has syntactic sugar, so translate it into real code.

Step 1

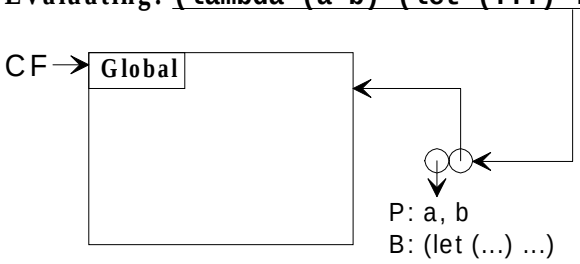
Evaluating: (define quiz-cons (lambda (a b) ...))



Define is a special form. We must evaluate the expression to find out what the name *quiz-cons* will point to.

Step 2

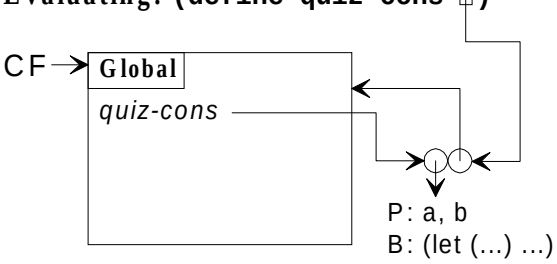
Evaluating: (lambda (a b) (let (...) ...))



Lambda is a special form. This creates a procedure which is drawn as a bubble pair. One bubble points to the parameters and body of the procedure. The other bubble points to the frame it was evaluated in (the Current Frame).

Step 3

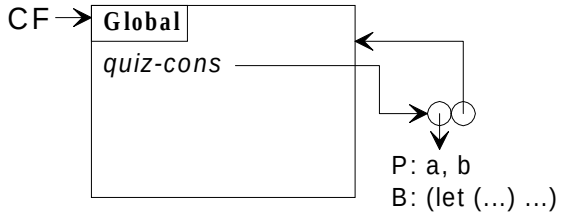
Evaluating: (define quiz-cons □)



The expression in the *define* special form has been evaluated, now we create the name *quiz-cons* in the current frame and make it point to the result of the evaluated expression.

Step 4

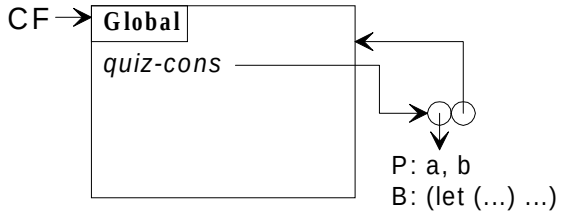
Evaluating: (define apple (quiz-cons 'apple 'core))



Define is a special form. We must evaluate the expression to find out what the name *apple* will point to.

Step 5

Evaluating: (quiz-cons 'apple 'core)



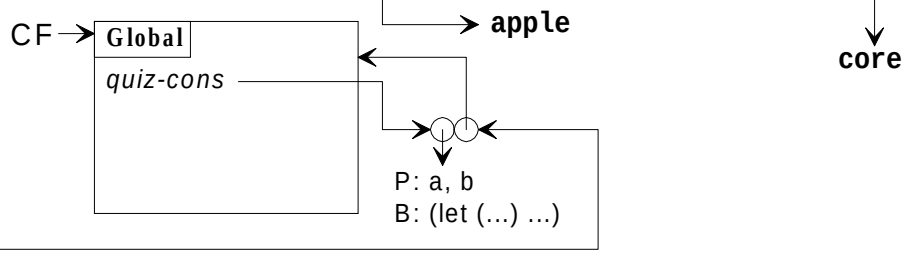
This expression is not a special form. Each sub-expression must be evaluated (in any order).

Step 6

Evaluating: quiz-cons

Evaluating: 'apple

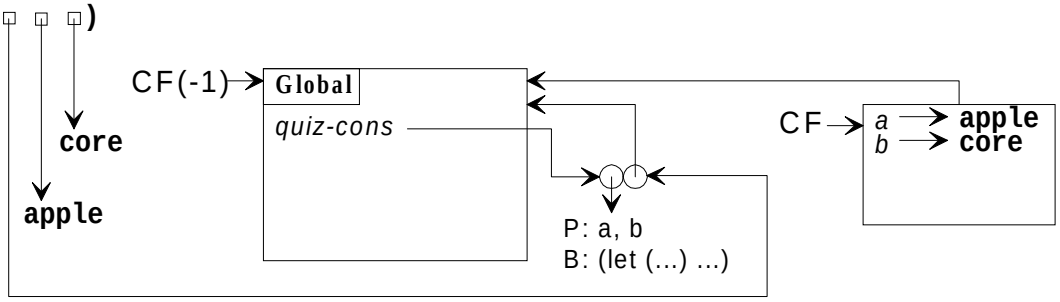
Evaluating: 'core



Evaluating the name *quiz-cons*, we look in the current frame and find the name exists, so it evaluates to what *quiz-cons* points to in the current frame. Evaluating *'apple* returns the symbol **apple**. Likewise, evaluating *'core* returns the symbol **core**.

Step 7

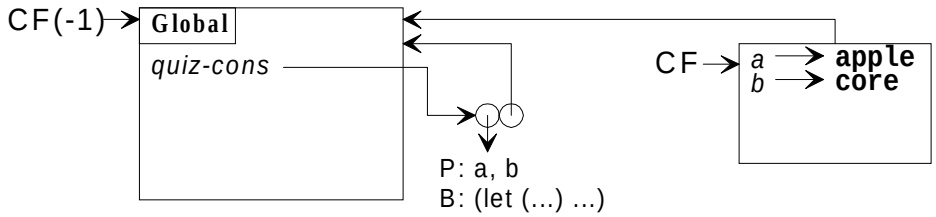
Evaluating: ( )



This expression is not a special form. Now that each expression has been evaluated, the first expression is a procedure (or an error occures) and it is evaluated with the given arguments (a wrong number of arguments is also an error). When the procedure is evaluated, a frame is created that points to the same frame the evaluated procedure points to. The parameter names are bound in the frame with the proper arguments. The CF pointer moves to the new frame and starts evaluating the body of the procedure. All previous CFs I'll label as CF(-n) so we know where to return when the body of the procedure has been evaluated.

Step 8

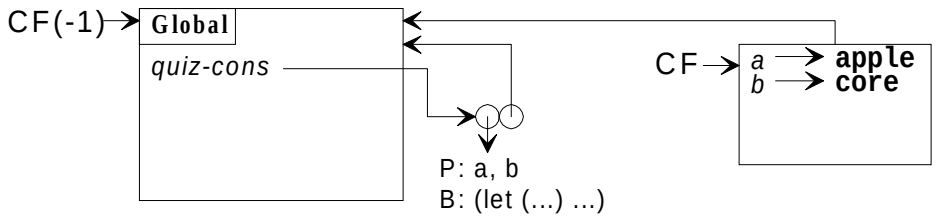
Evaluating: `(let ((cons (cons a b))) (lambda (mesg) ...))`



The *let* expression is syntactic sugar for an evaluated lambda.
We must translate this into real code.

Step 9

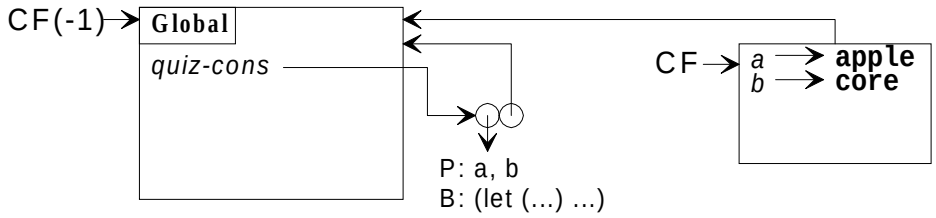
Evaluating: `((lambda (cons) (lambda (mesg) ...)) (cons a b))`



Now that we have removed the syntactic sugar, we see that this expression is not a special form. Each sub-expression must be evaluated (in any order).

Step 10

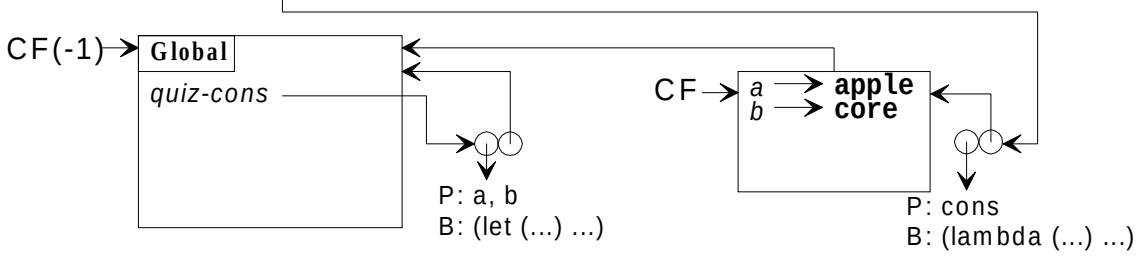
Evaluating: ((lambda (cons) (lambda (mesg) ...)) (cons a b))



Now that we have removed the syntactic sugar, we see that this expression is not a special form. Each sub-expression must be evaluated (in any order).

Step 11

Evaluating: (lambda (cons) (lambda (mesg) ...)) **Evaluating: (cons a b)**

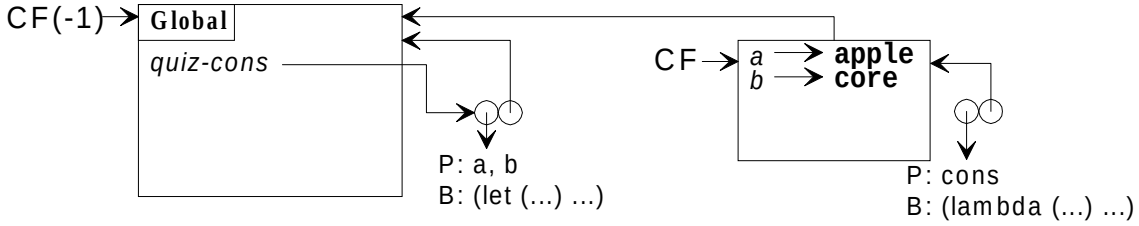


We evaluate the *lambda* special form as we did before, drawing the bubble pair. The other expression is not a special form and each sub-expression must be evaluated (in any order).

Step 12

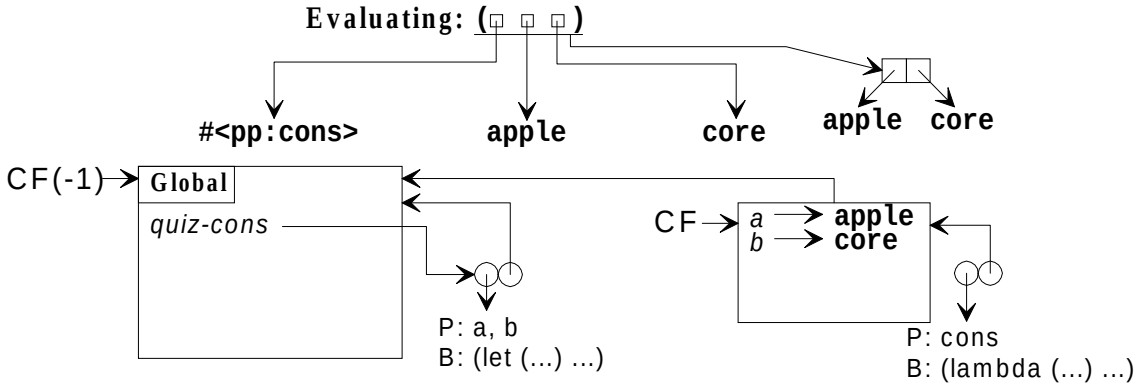
Evaluating: cons **Evaluating: a** **Evaluating: b**

#<pp:cons> **apple** **core**



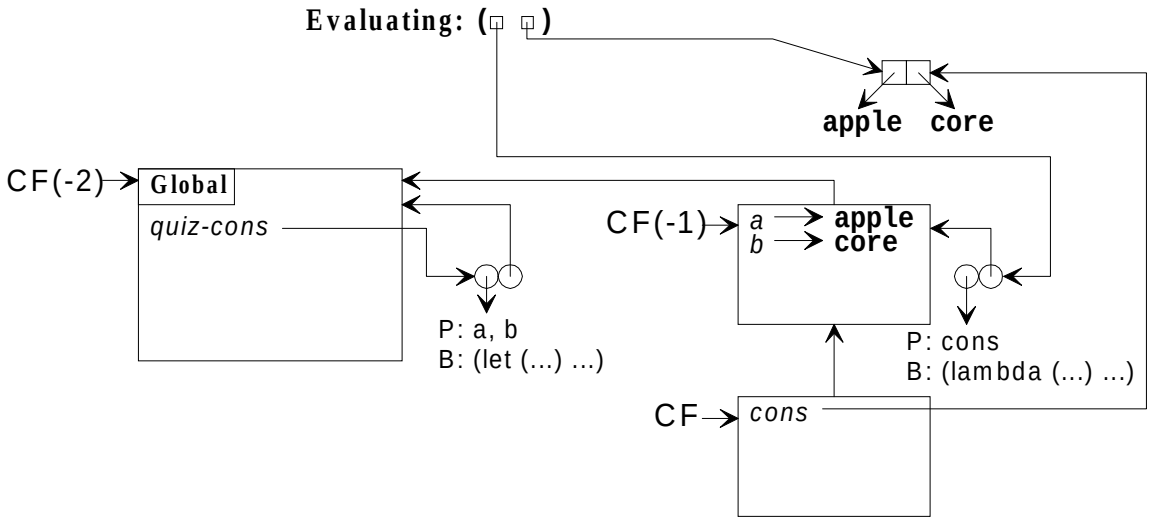
To evaluate the name *cons*, we must check the current frame, but don't find it, so we check the frame pointed to by the current frame, and check there. *Cons* is defined in the Global Environment as a primitive procedure (a built in procedure). I draw it as **#<pp:cons>**.
To evaluate the name *a* we check the current frame and find it evaluates to the symbol **apple**.
To evaluate the name *b* we check the current frame and find it evaluates to the symbol **core**.

Step 13



Now that each expression inside this expression has been evaluated, we can evaluate this expression. The primitive procedure *cons* makes a pair who's first argument is the car and the second is the cdr. (Note: no frames are made for primitve procedures.)

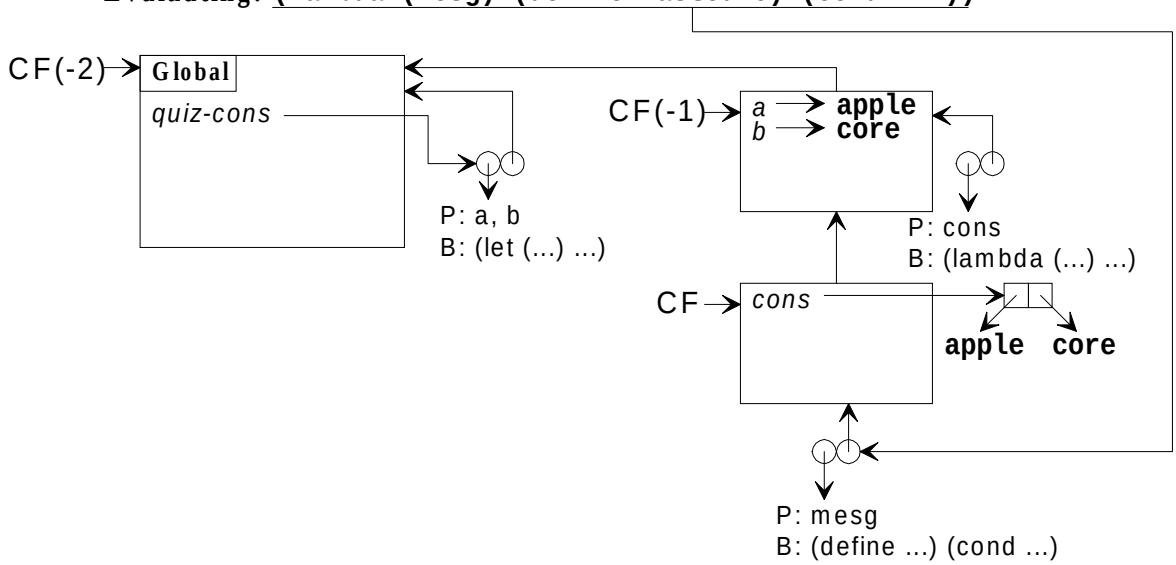
Step 14



Now that each expression inside this expression has been evaluated, we can evaluate this expression. This is not a special form, the given procedure is applied to the given arguments. This creates a new frame that points to the frame the procedure called points to, and the arguments are bound to the proper parameter names inside the frame. Now the CF pointer is moved and the body of the procedure is evaluated.

Step 15

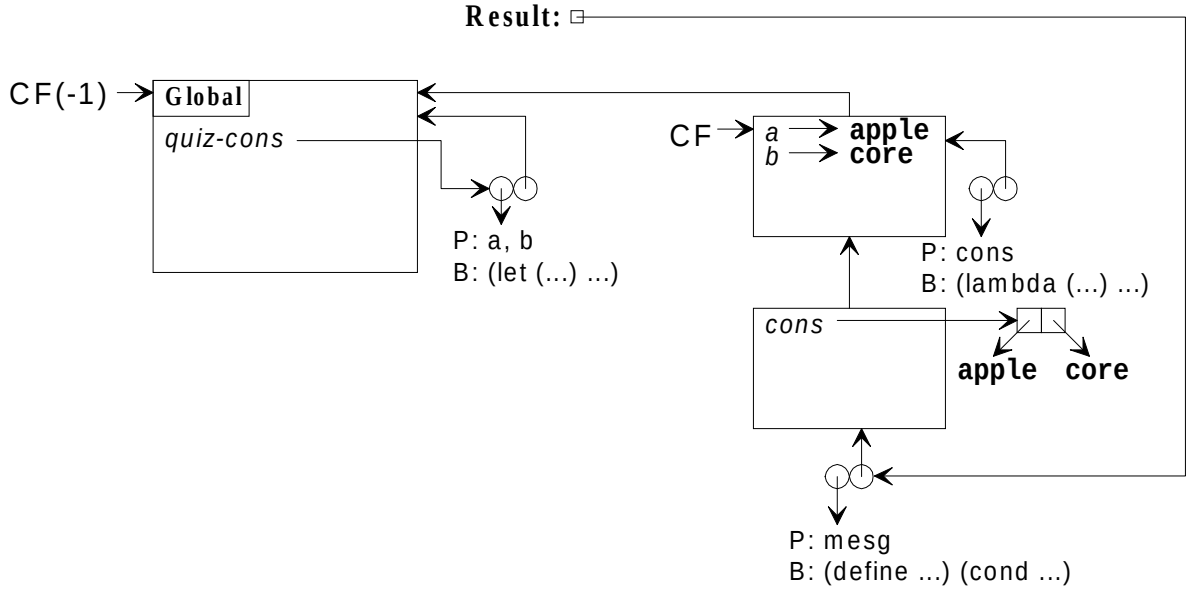
Evaluating: `(lambda (mesg) (define wasted 6) (cond ...))`



We evaluate the *lambda* special form as we did before, drawing the bubble pair. Since this is the last expression to be evaluated in this procedure, the evaluation result becomes the return value of the procedure. We will be moving back to the previous CF and finish evaluating the procedure that this procedure was evaluated in.

Step 16

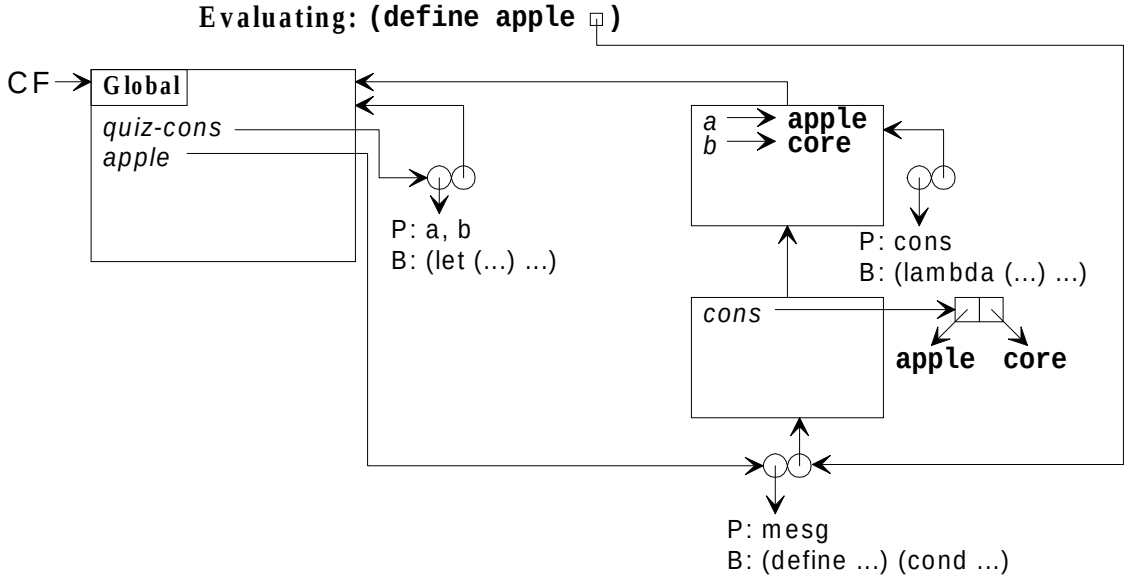
Result: ⊡



After returning the result, we notice that this is the result of evaluating the last expression in this procedure. This means this is also the result of evaluating this procedure.

Step 17

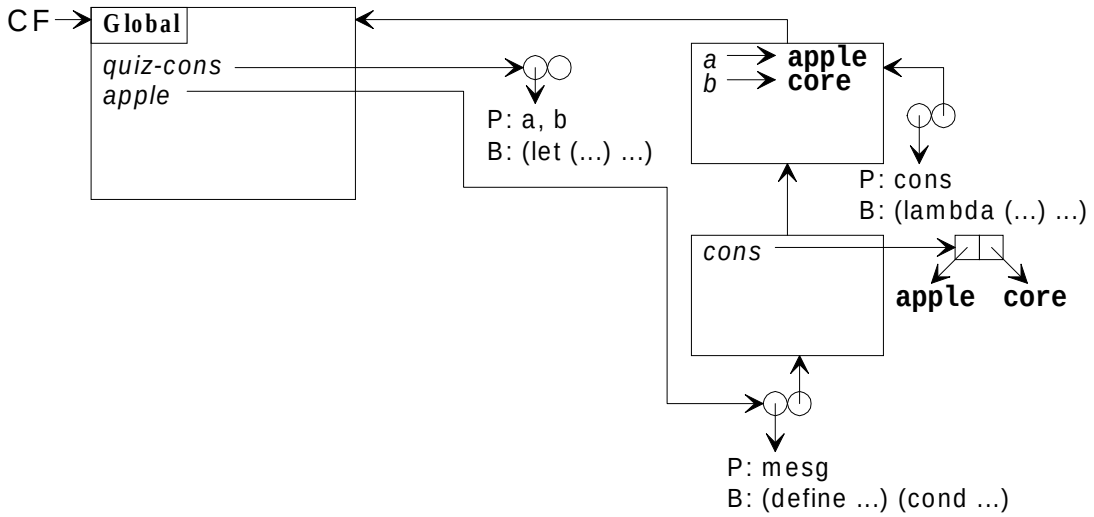
Evaluating: (define apple □)



Now that we have evaluated the expression in the *define* special form, we bind the name *apple* in the Current Frame to the result.

Step 18

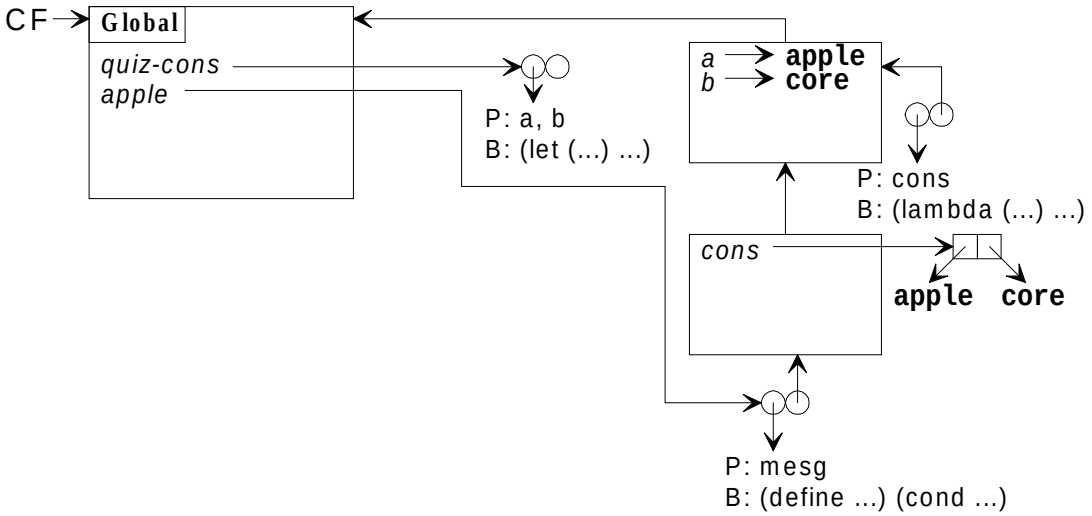
Evaluating: (define no-apple (quiz-cons 'apple "Oh! There's more!"))



Define is a special form. We must evaluate the expression to find out what the name *no-apple* will point to.

Step 19

Evaluating: (quiz-cons 'apple "Oh! There's more!")

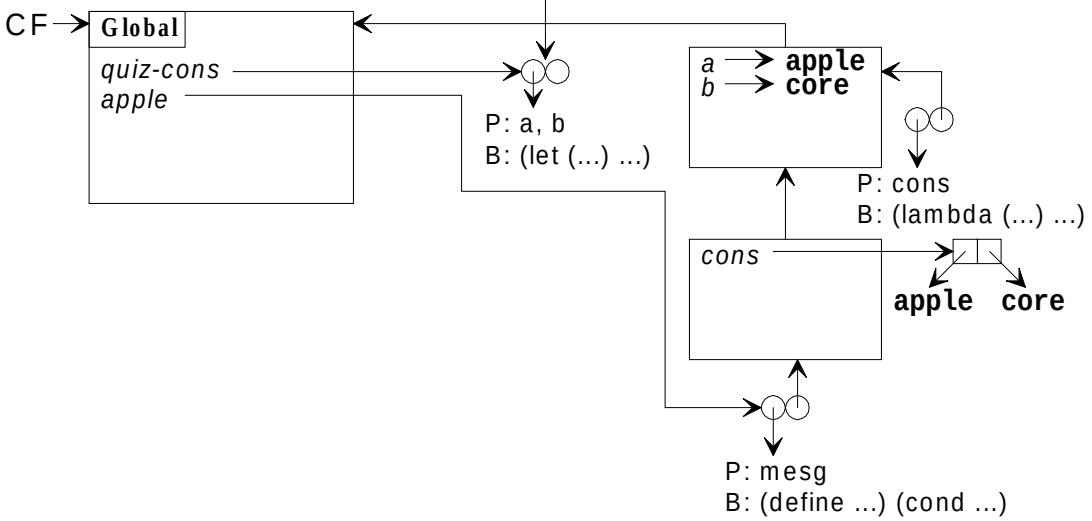


This expression is not a special form. Each sub-expression must be evaluated (in any order).

Step 20

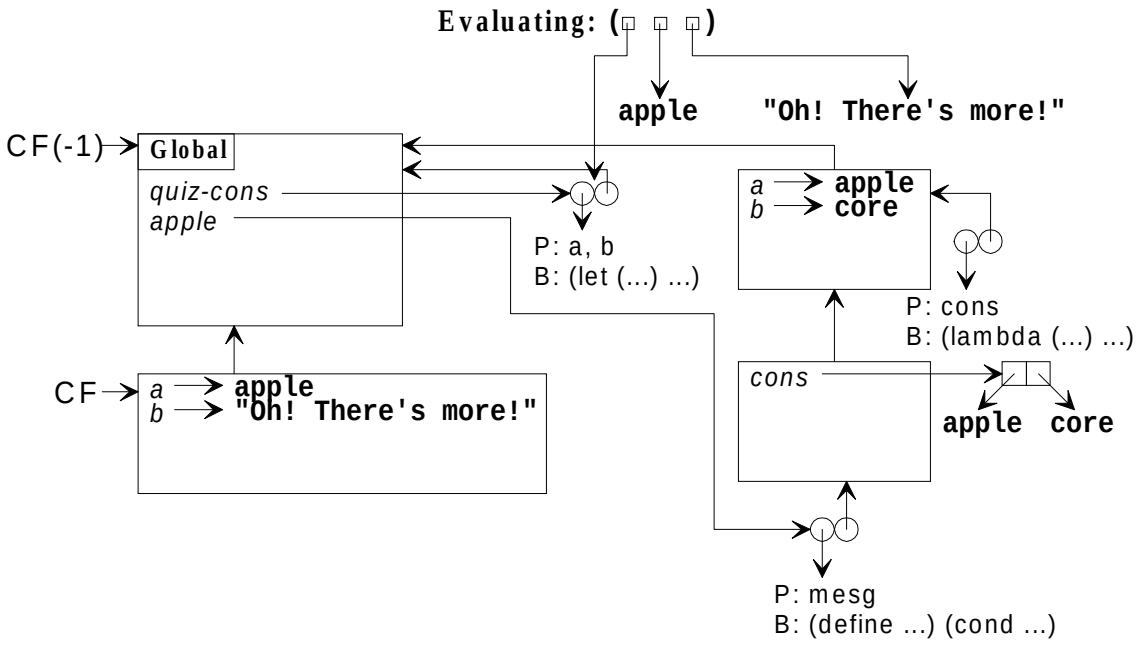
Evaluating: (quiz-cons 'apple "Oh! There's more!")

apple **"Oh! There's more!"**



Evaluating the name *quiz-cons*, we look in the current frame and find the name exists, so it evaluates to what *quiz-cons* points to in the current frame. Evaluating *'apple* returns the symbol **apple**. Evaluating the string *"Oh There's more!"* returns the string "**Oh There's more!**".

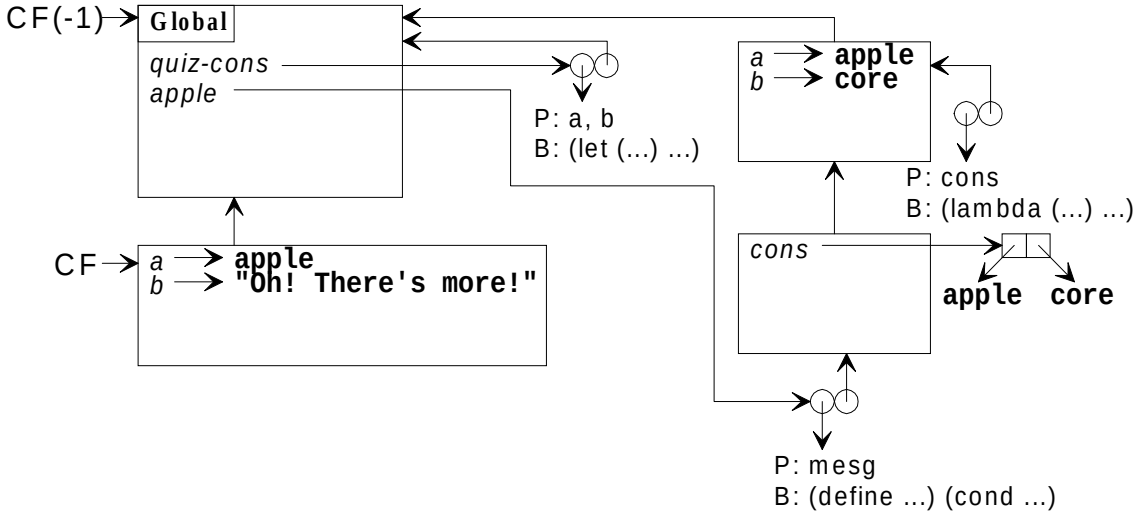
Step 21



Now that each expression inside this expression has been evaluated, we can evaluate this expression. This is not a special form, the given procedure is applied to the given arguments. This creates a new frame that points to the frame the procedure called points to, and the arguments are bound to the proper parameter names inside the frame. Now the CF pointer is moved and the body of the procedure is evaluated.

Step 22

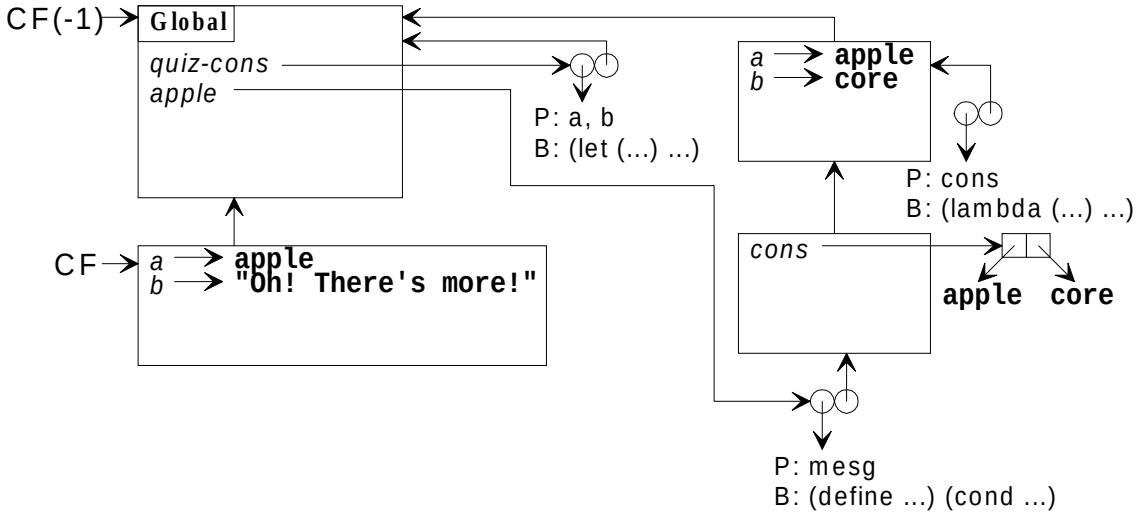
Evaluating: (let ((cons (cons a b))) (lambda (mesg) ...))



The *let* expression is syntactic sugar for an evaluated lambda.
We must translate this into real code.

Step 23

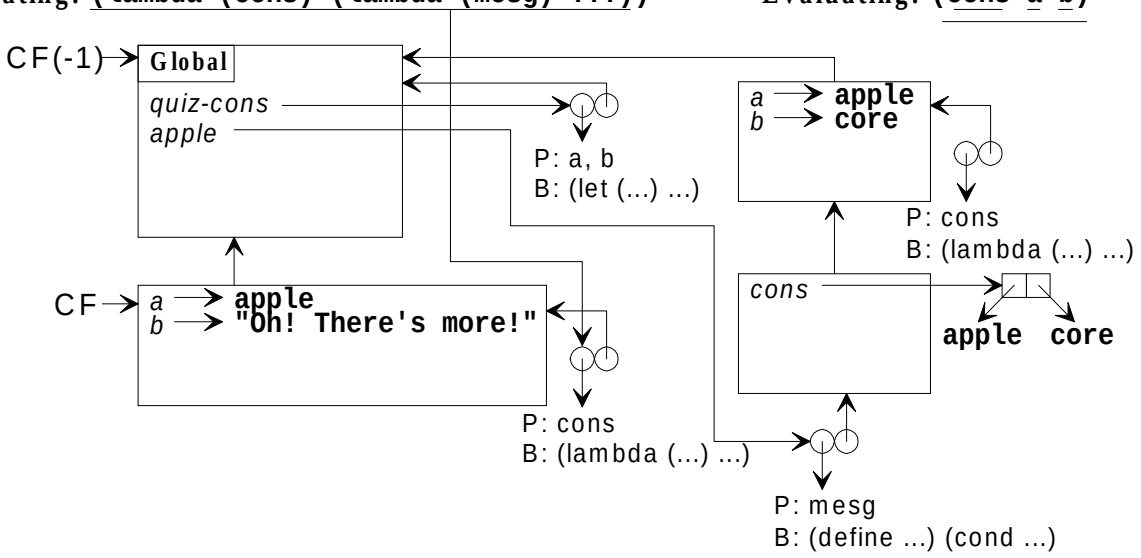
Evaluating: ((lambda (cons) (lambda (mesg) ...)) (cons a b))



Now that we have removed the syntactic sugar, we see that this expression is not a special form. Each sub-expression must be evaluated (in any order).

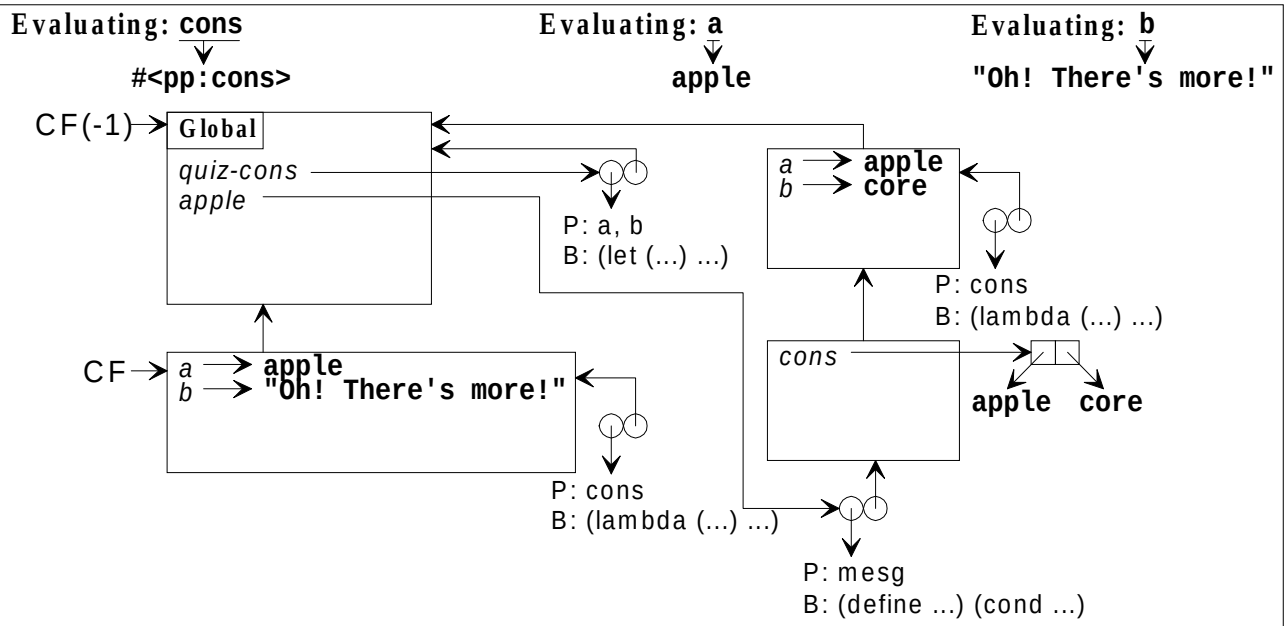
Step 24

Evaluating: (lambda (cons) (lambda (mesg) ...)) **Evaluating: (cons a b)**



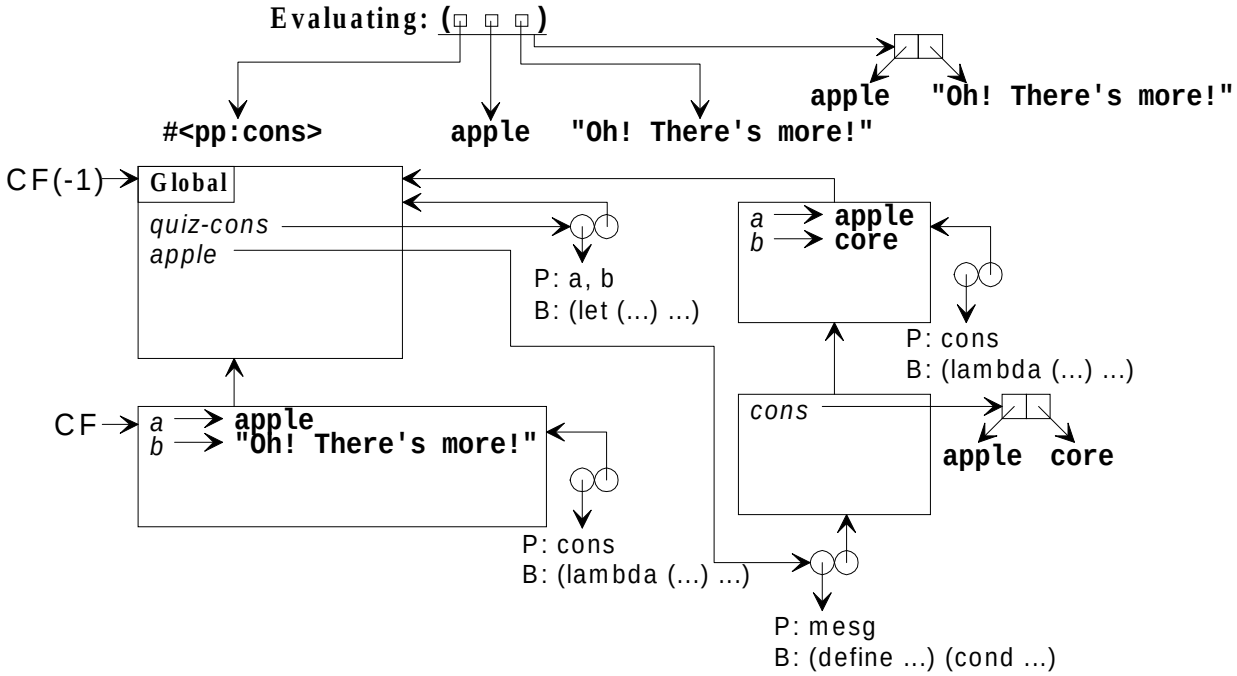
We evaluate the *lambda* special form as we did before, drawing the bubble pair. The other expression is not a special form and each sub-expression must be evaluated (in any order).

Step 25



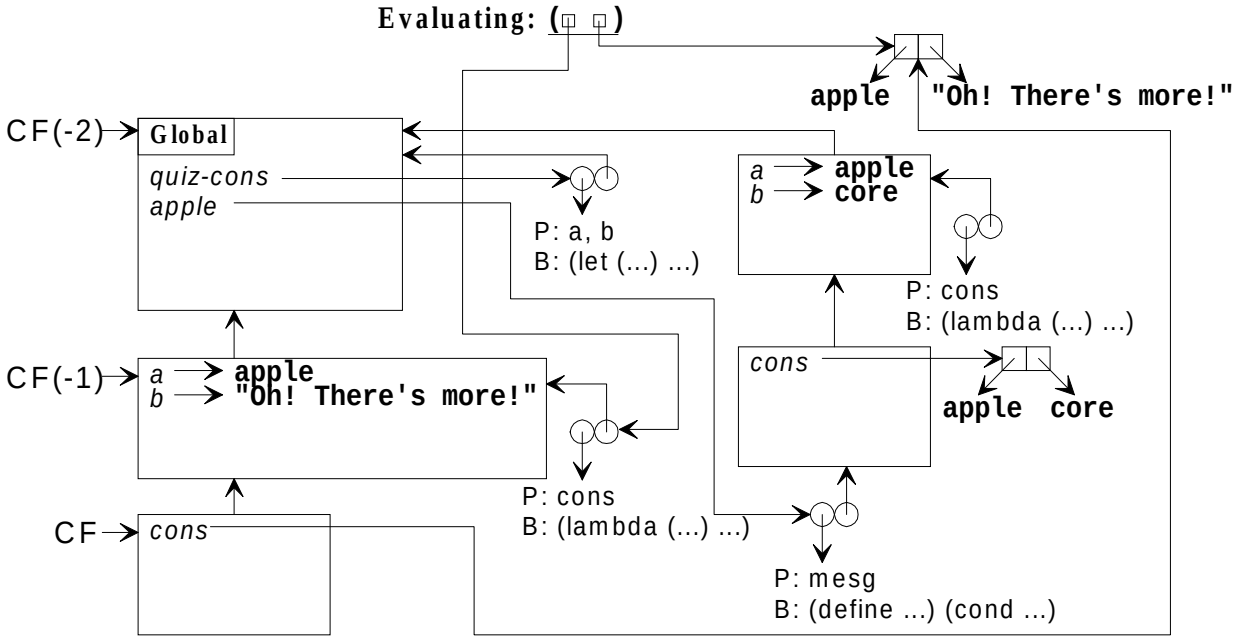
To evaluate the name *cons*, we must check the current frame, but don't find it, so we check the frame pointed to by the current frame, and check there. *Cons* is defined in the Global Environment as a primitive procedure (a built in procedure). I draw it as **#<pp:cons>**.
To evaluate the name *a* we check the current frame and find it evaluates to the symbol **apple**.
To evaluate the name *b* we check the current frame and find it evaluates to the string **"Oh! There's more!"**.

Step 26



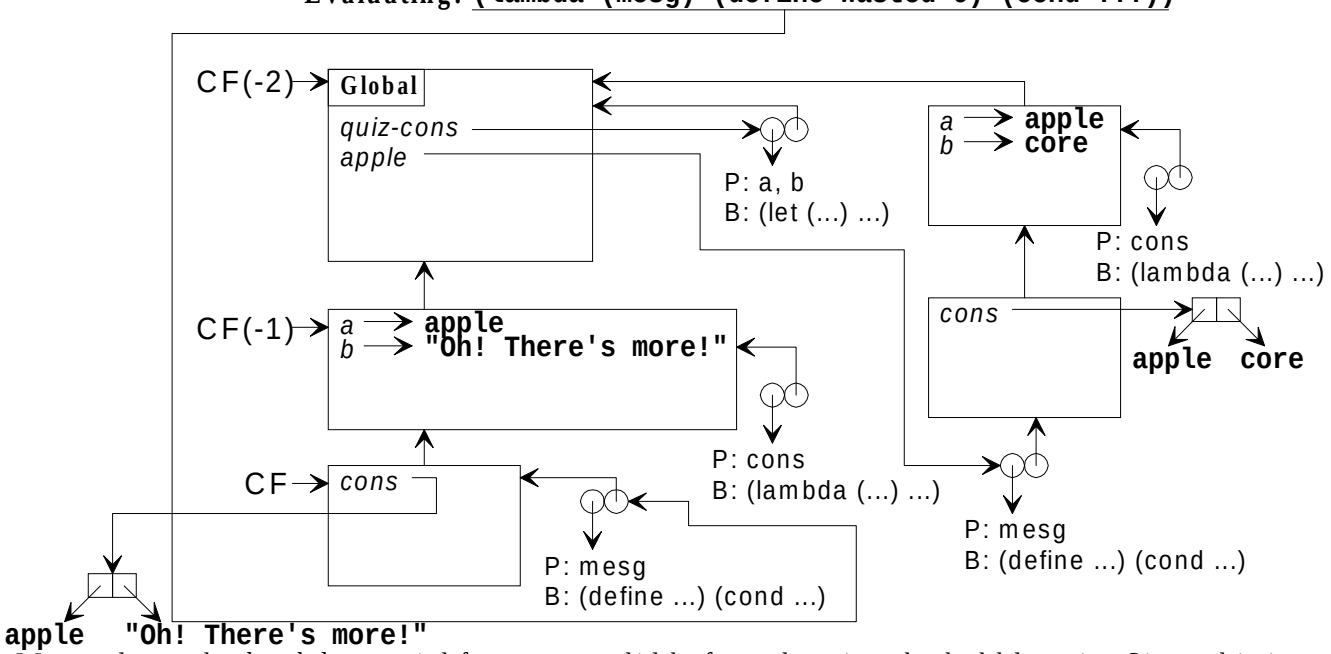
Now that each expression inside this expression has been evaluated, we can evaluate this expression. The primitive procedure *cons* makes a pair who's first argument is the car and the second is the cdr. (Note: no frames are made for primitve procedures.)

Step 27



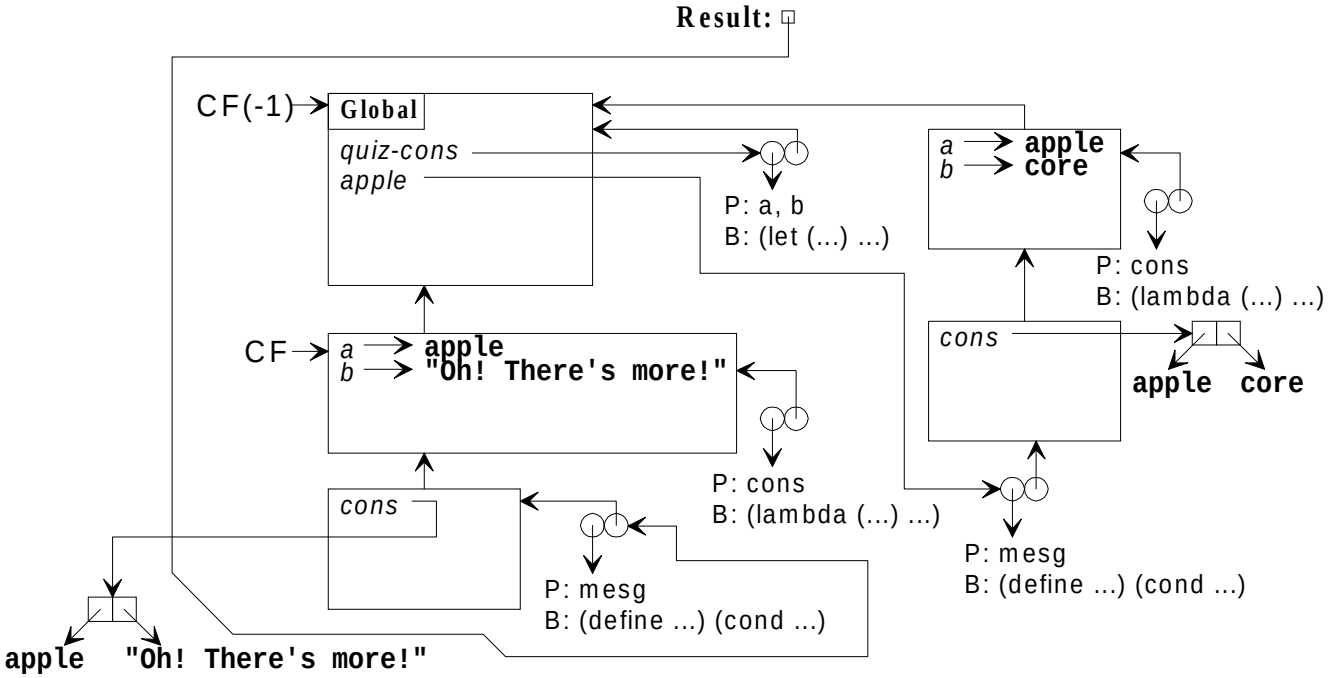
Now that each expression inside this expression has been evaluated, we can evaluate this expression. This is not a special form, the given procedure is applied to the given arguments. This creates a new frame that points to the frame the procedure called points to, and the arguments are bound to the proper parameter names inside the frame. Now the CF pointer is moved and the body of the procedure is evaluated.

Step 28



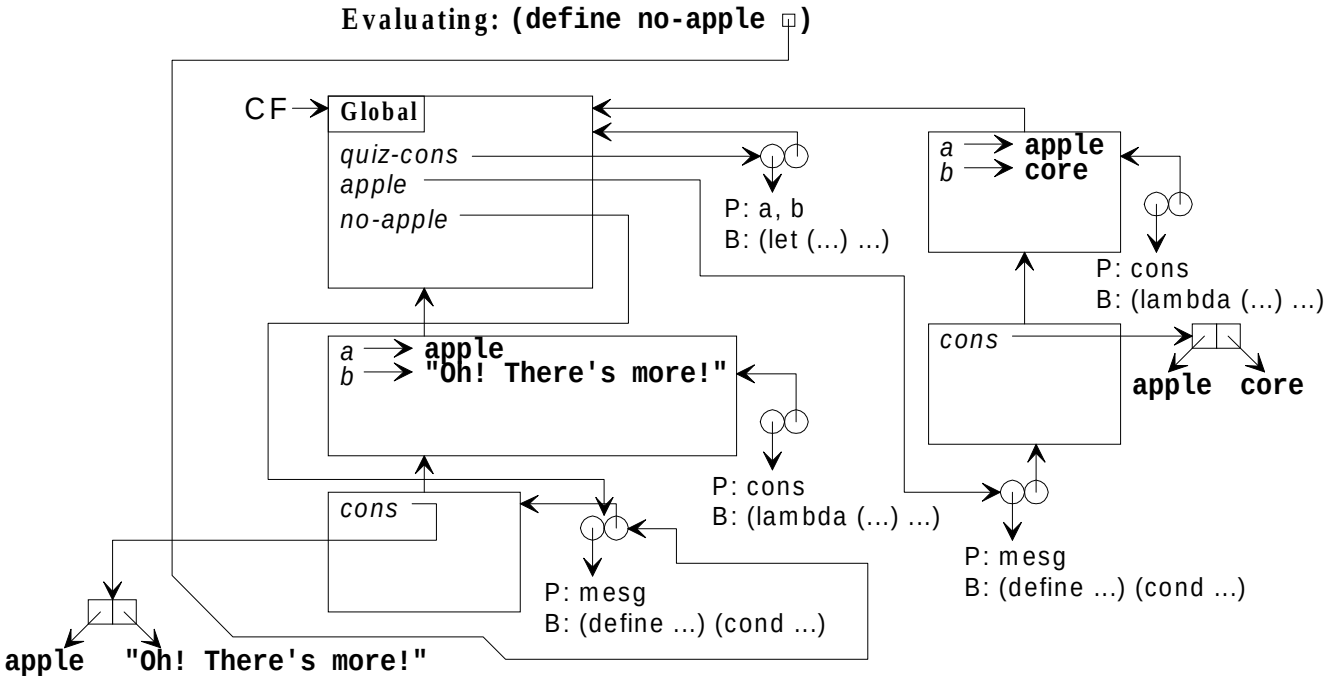
We evaluate the *lambda* special form as we did before, drawing the bubble pair. Since this is the last expression to be evaluated in this procedure, the evaluation result becomes the return value of the procedure. We will be moving back to the previous CF and finish evaluating the procedure that this procedure was evaluated in.

Step 29



After returning the result, we notice that this is the result of evaluating the last expression in this procedure. This means this is also the result of evaluating this procedure.

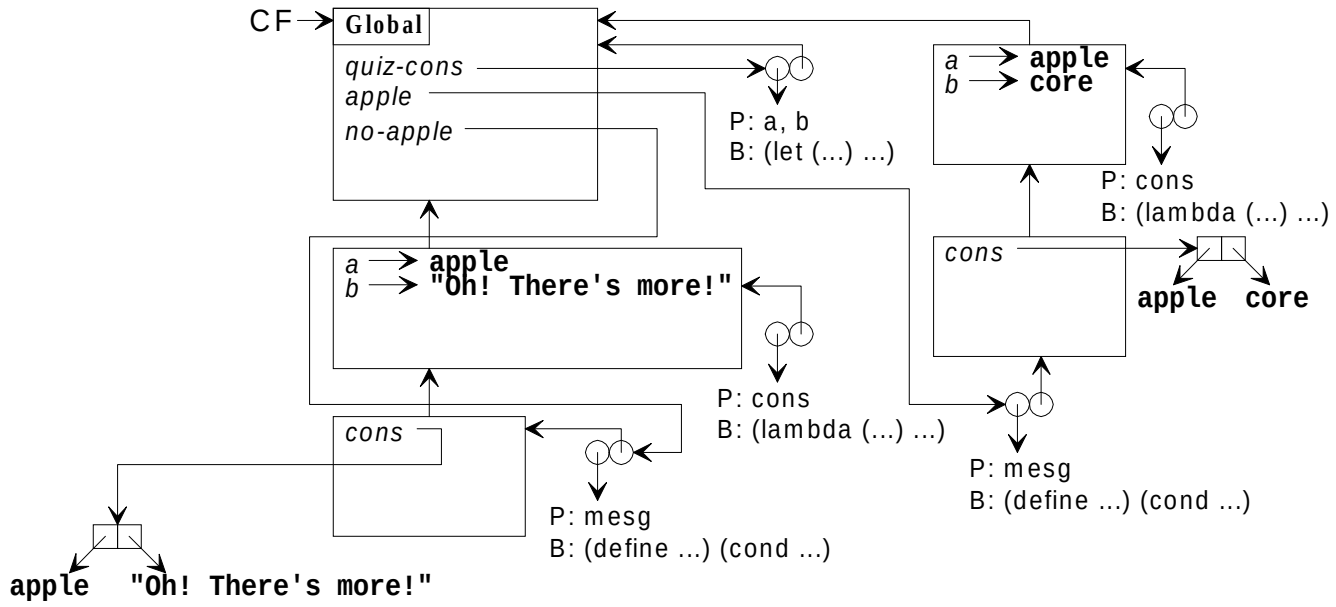
Step 30



Now that we have evaluated the expression in the *define* special form, we bind the name *no-apple* in the Current Frame to the result.

Step 31

Evaluating: (cdr (no-apple 'cons))



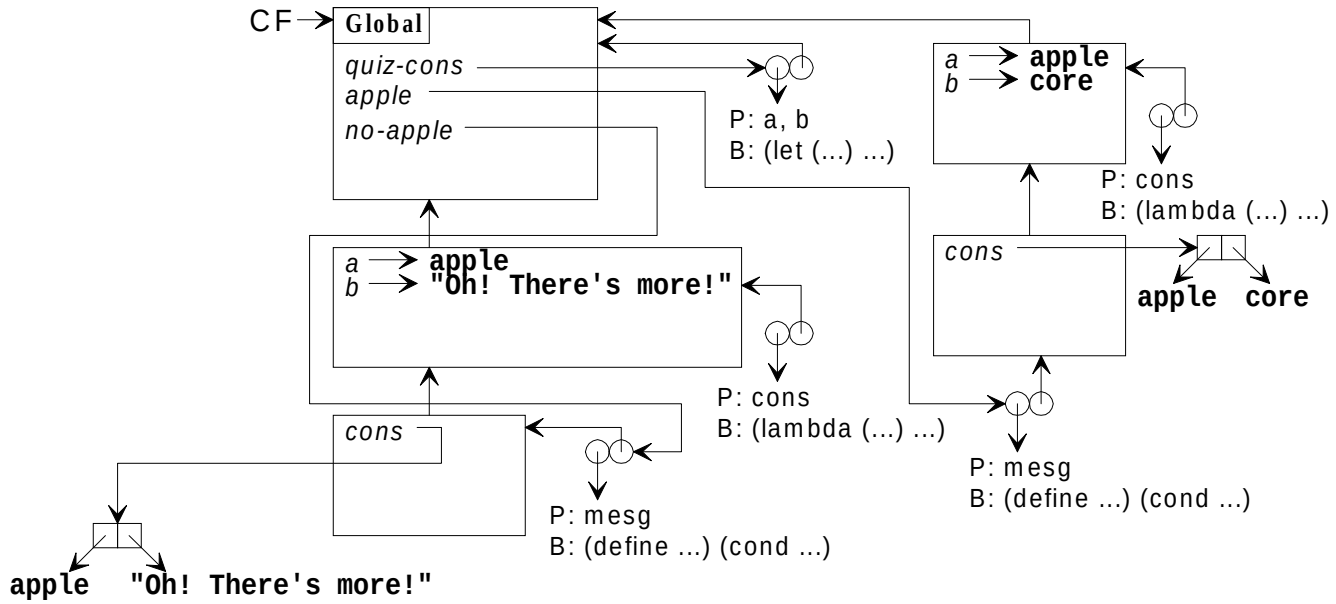
This expression is not a special form. Each sub-expression must be evaluated (in any order).

Step 32

Evaluating: cdr

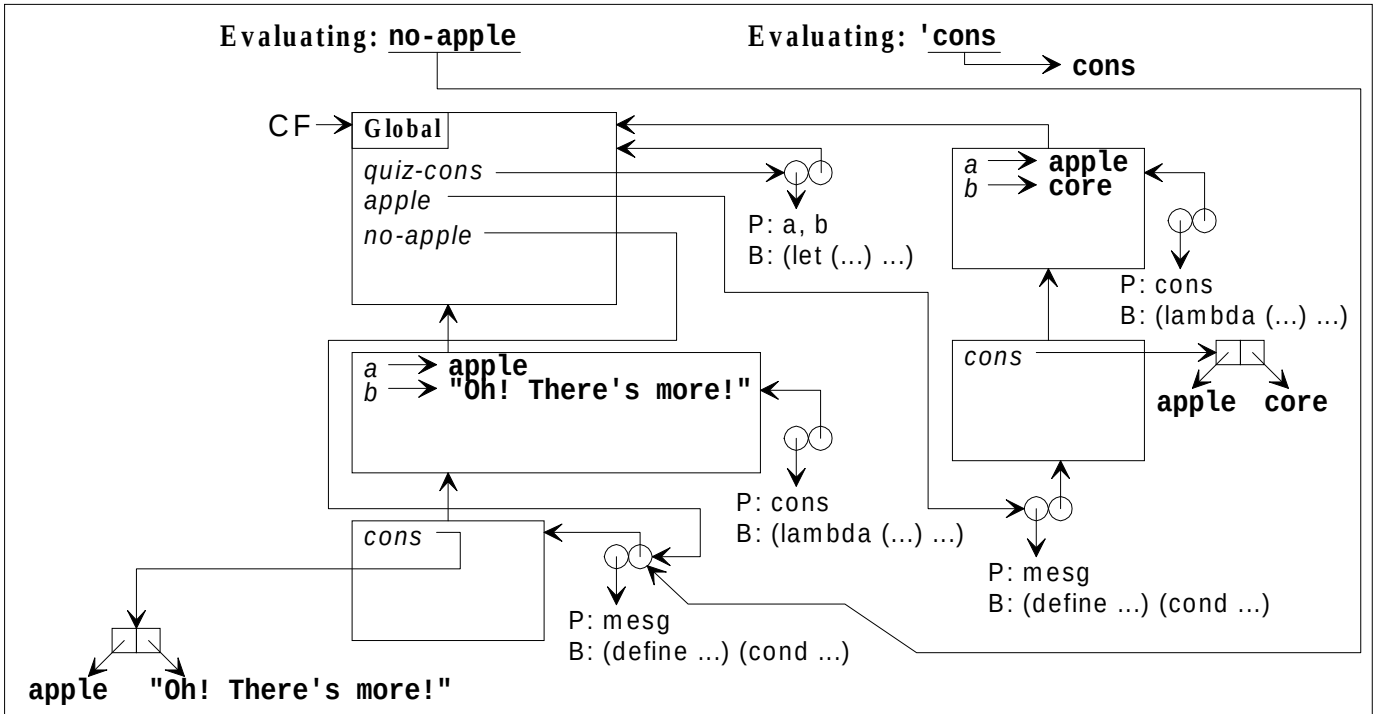
#<pp:cdr>

Evaluating: (no-apple 'cons)



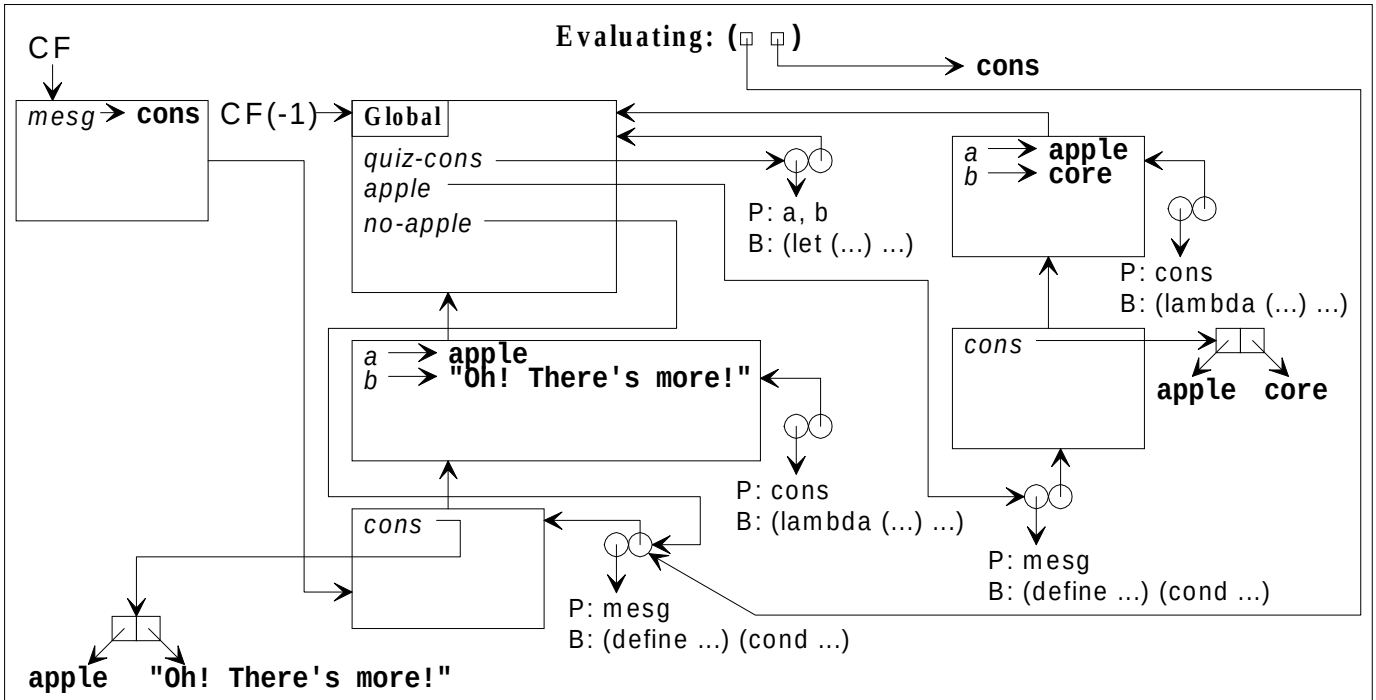
To evaluate the name *cdr*, we must check the current frame, and find it because it is defined in the Global Environment as a primitive procedure (a built in procedure). I draw it as **#<pp:cdr>**. The second expression is not a special form and each sub-expression must be evaluated (in any order).

Step 33



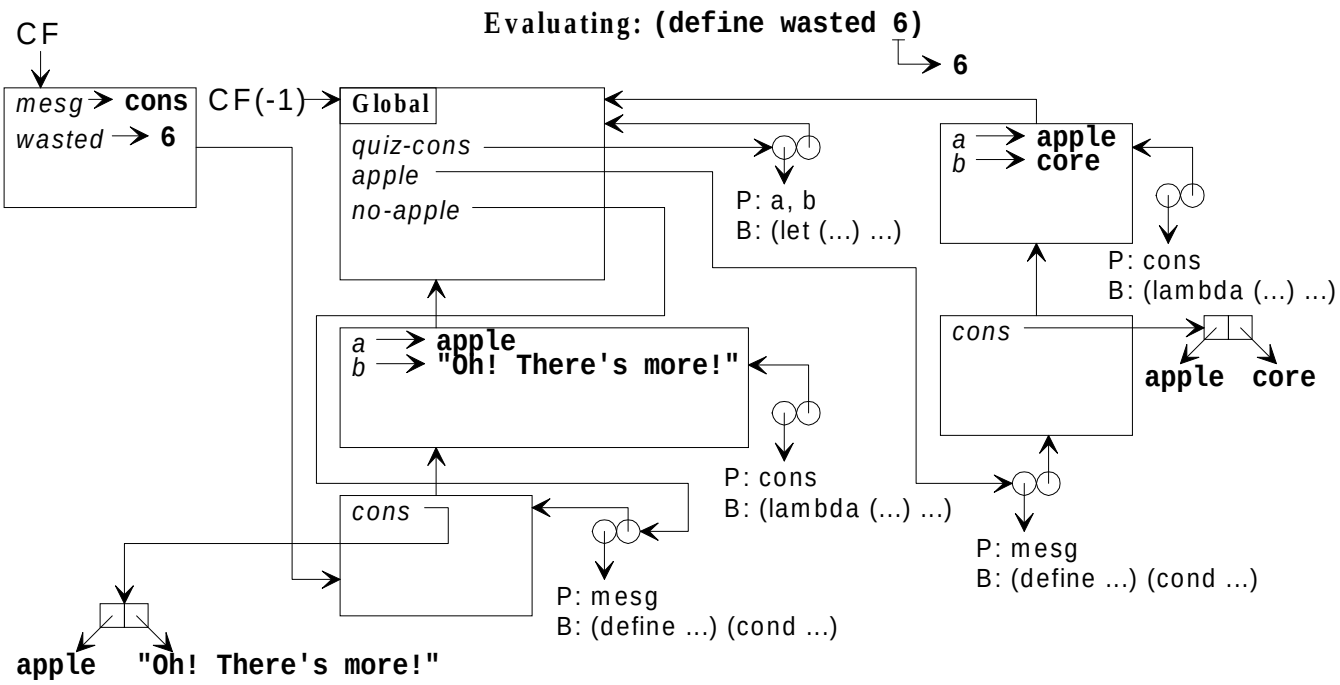
To evaluate the name *no-apple*, we check the current frame, find it, and use the result. Evaluating *'cons* returns the symbol **cons**.

Step 34



Now that each expression inside this expression has been evaluated, we can evaluate this expression. This is not a special form, the given procedure is applied to the given arguments. This creates a new frame that points to the frame the procedure called points to, and the arguments are bound to the proper parameter names inside the frame. Now the CF pointer is moved and the body of the procedure is evaluated.

Step 35

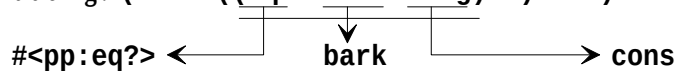


Define is a special form. We must evaluate the expression to find out what the name quiz-cons will point to. The *6* evaluates to the value **6**. This result is then bound to the name *wasted* in the Current Frame.

Step 36

For Steps 37 through 43, refer to the Environment Diagram in Step 36. They all look alike.

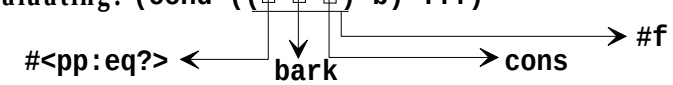
Evaluating: (cond ((eq? 'bark mesg) b) ...)



Cond is a special form, so first we need to evaluate the first conditional expression.
To evaluate it, we need to evaluate all of the parts. The name *eq?* follows the path of pointers to frames from the Current Frame until the Global Environment (since it is undefined in all of the frames inbetween), and is found to be a primitive procedure, **#<pp:eq?>**. *'bark* evaluates to the symbol **bark**. The name *mesg* is found in the Current Frame and evaluates to **cons**.

Step 37

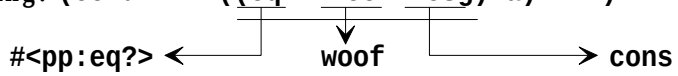
Evaluating: (cond ((□ □ □) b) ...)



Evaluating the primitive procedure **eq?** on the symbols **bark** and **cons** results in **#f** because they are unequal. The result of **#f** in the *cond* expression causes us to move on to the next conditional predicate and evaluate it.

Step 38

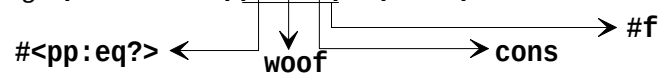
Evaluating: (cond ... ((eq? 'woof mesg) a) ...)



Cond is a special form, so first we need to evaluate the first conditional expression.
To evaluate it, we need to evaluate all of the parts. The name *eq?* follows the path of pointers to frames from the Current Frame until the Global Environment (since it is undefined in all of the frames inbetween), and is found to be a primitive procedure, **#<pp:eq?>**. *'woof* evaluates to the symbol **woof**. The name *mesg* is found in the Current Frame and evaluates to **cons**.

Step 39

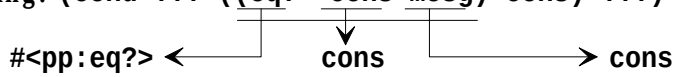
Evaluating: (cond ... ((□ □ □) a) ...)



Evaluating the primitive procedure **eq?** on the symbols **woof** and **cons** results in **#f** because they are unequal. The result of **#f** in the *cond* expression causes us to move on to the next conditional predicate and evaluate it.

Step 40

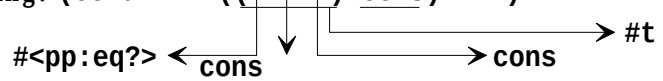
Evaluating: (cond ... ((eq? 'cons mesg) cons) ...)



Cond is a special form, so first we need to evaluate the first conditional expression.
To evaluate it, we need to evaluate all of the parts. The name *eq?* follows the path of pointers to frames from the Current Frame until the Global Environment (since it is undefined in all of the frames inbetween), and is found to be a primitive procedure, **#<pp:eq?>**. *'cons* evaluates to the symbol **cons**. The name *mesg* is found in the Current Frame and evaluates to **cons**.

Step 41

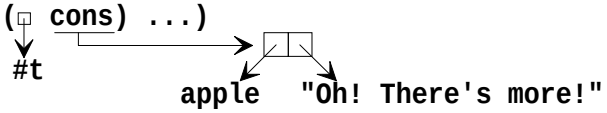
Evaluating: (cond ... ((□ □ □) cons) ...)



Evaluating the primitive procedure **eq?** on the symbols **cons** and **cons** results in **#t** because they are equal. The result of **#t** in the *cond* expression causes us to evaluate the clause associated with this predicate.

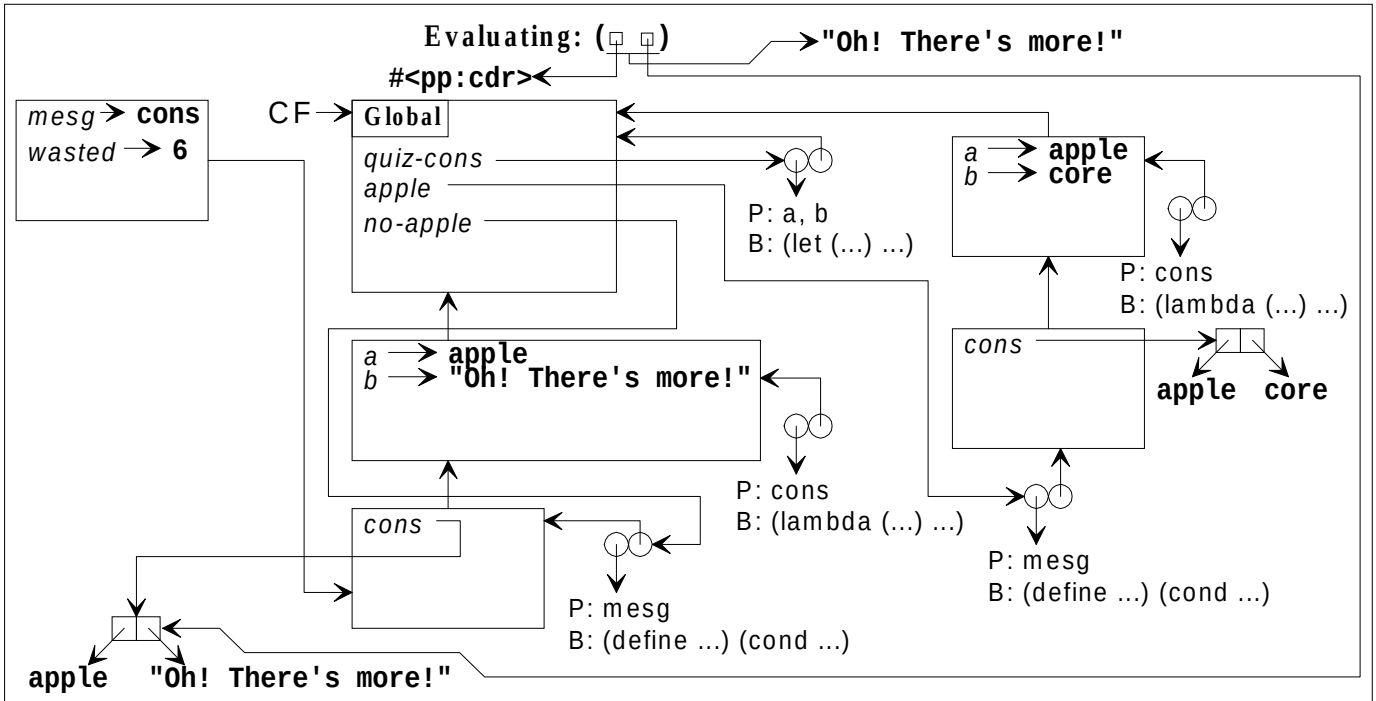
Step 42

Evaluating: (cond ... (□ cons) ...)



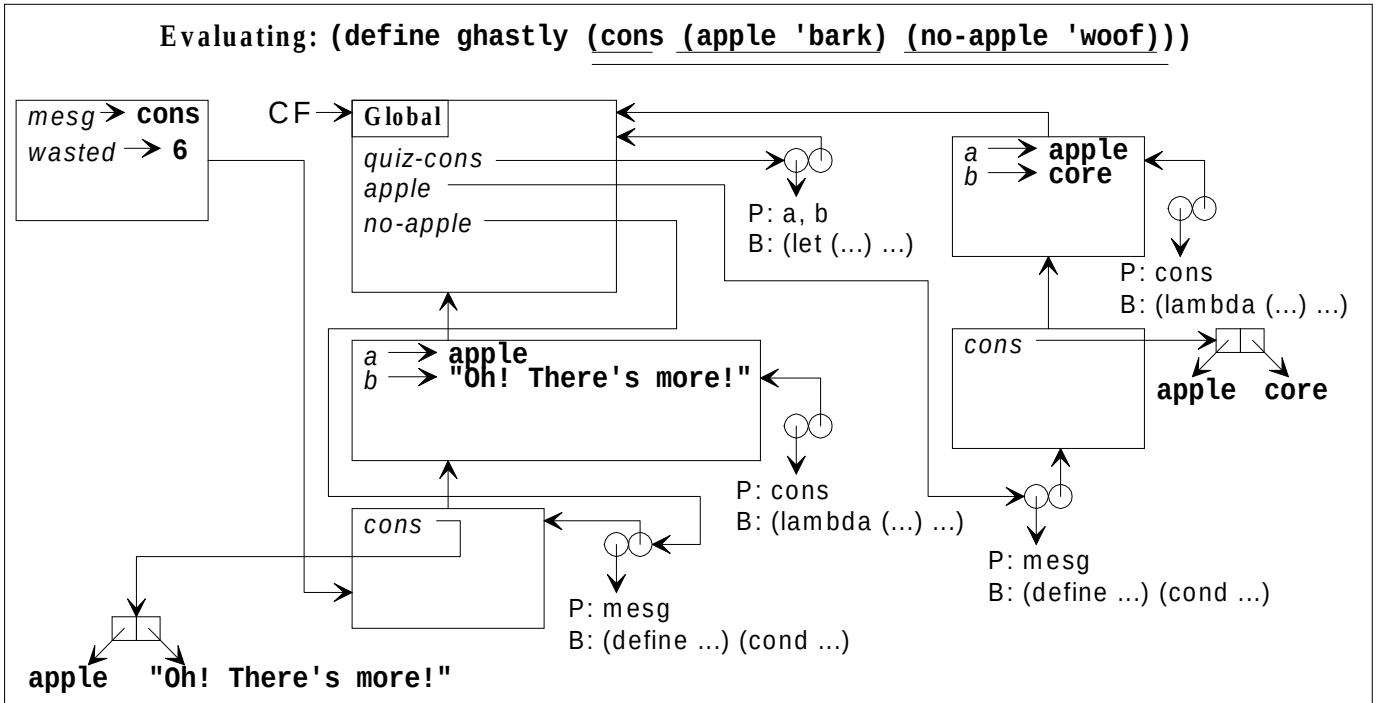
To evaluate the name *cons* we look in the Current Frame, don't find it, and then look in the frame pointed to by the Current Frame, and find it is equal to a paticular pair. Note that the pair I'm drawing represents exactly the same pair, and is not a duplicate! Since this is the last expression in the predicate, and the *cond* expression was the last expression in the procedure, the result of the procedure is the result of evaluating the name *cons* in the Current Frame, and we move the CF pointer back to the Global Environment and leave the procedure.

Step 43



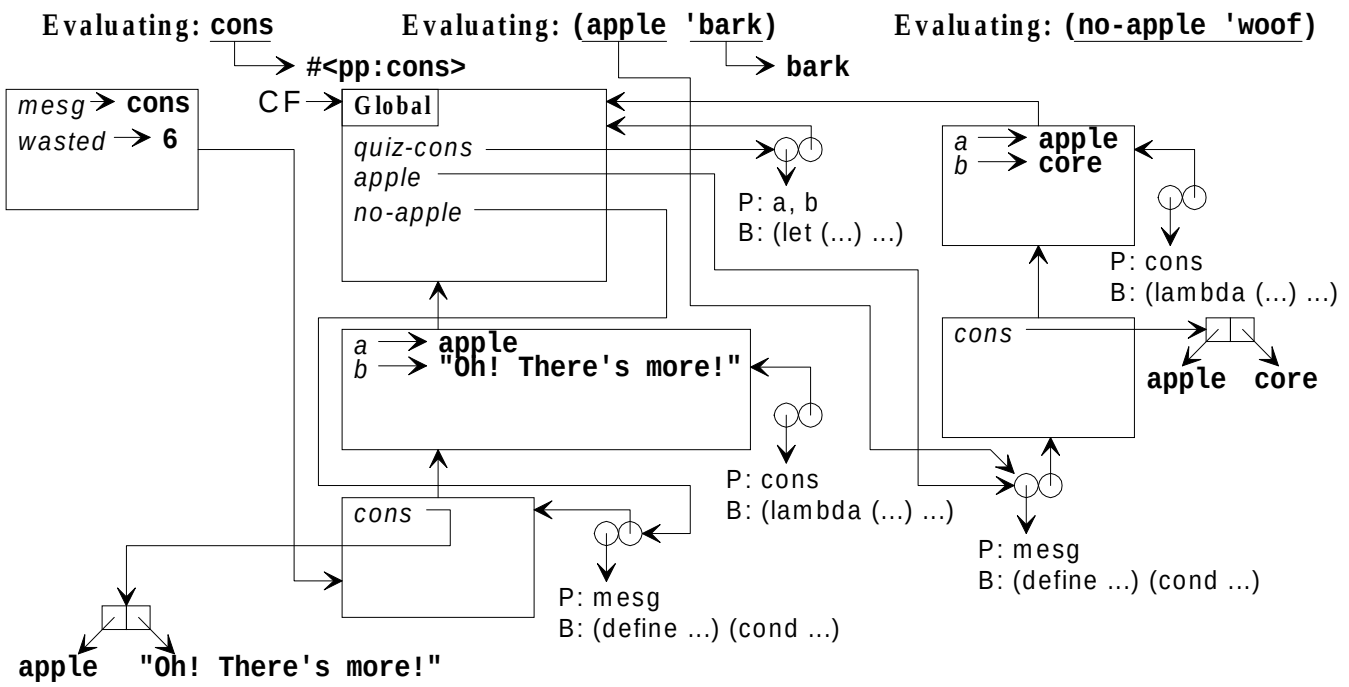
Now that we have evaluated all of the expressions with this expression, we note that it isn't a special form and evaluate the primitive procedure **cdr** on the given argument. The result, **"Oh! There's more!"**, is then returned to the user at the prompt because that's who evaluated it.

Step 44



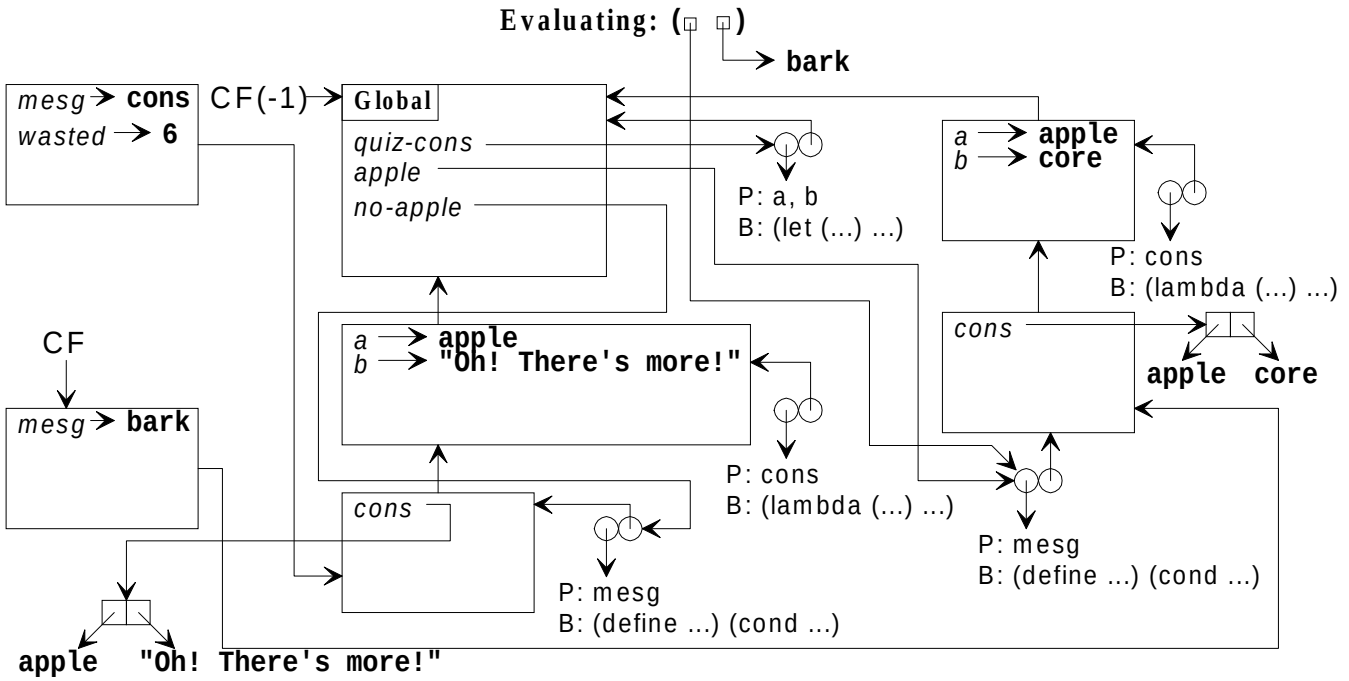
Define is a special form. We must evaluate the expression to find out what the name *ghastly* will point to. That expression is made up of other expressions, so we need to evaluate them first.

Step 45



Evaluating the name *cons*, we find the primitive procedure **cons**. In order to evaluate the other expressions, their sub expressions must be evaluated. The name *apple* evaluates to the procedure it points to, and *'bark* evaluates to the symbol **bark**. Note that we don't evalute the last expression until we finish evaluating the one we've started on.

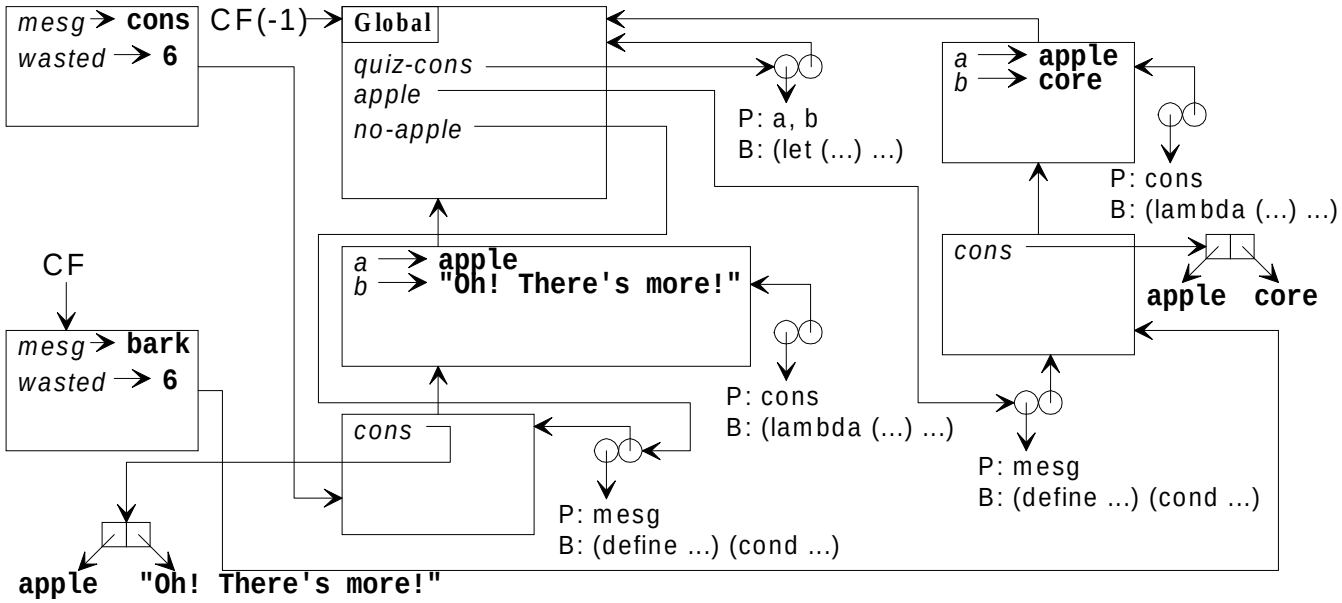
Step 46



Now that each expression inside this expression has been evaluated, we can evaluate this expression. This is not a special form, the given procedure is applied to the given arguments. This creates a new frame that points to the frame the procedure called points to, and the arguments are bound to the proper parameter names inside the frame. Now the CF pointer is moved and the body of the procedure is evaluated.

Step 47

Evaluating: (define wasted 6)

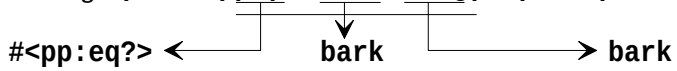


Define is a special form. We must evaluate the expression to find out what the name quiz-cons will point to. The *6* evaluates to the value **6**. This result is then bound to the name *wasted* in the Current Frame.

Step 48

For Steps 49 through 51, refer to the Environment Diagram in Step 48. They all look alike.

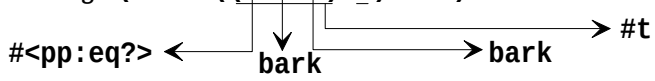
Evaluating: (cond ((eq? 'bark mesg) b) ...)



Cond is a special form, so first we need to evaluate the first conditional expression.
To evaluate it, we need to evaluate all of the parts. The name *eq?* follows the path of pointers to frames from the Current Frame until the Global Environment (since it is undefined in all of the frames inbetween), and is found to be a primitive procedure, **#<pp:eq?>**. *'bark* evaluates to the symbol **bark**. The name *mesg* is found in the Current Frame and evaluates to **bark**.

Step 49

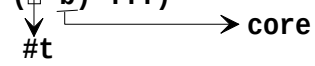
Evaluating: (cond ((□ □ □) b) ...)



Evaluating the primitive procedure **eq?** on the symbols **bark** and **bark** results in **#t** because they are equal. The result of **#t** in the *cond* expression causes us to evaluate the clause associated with this predicate.

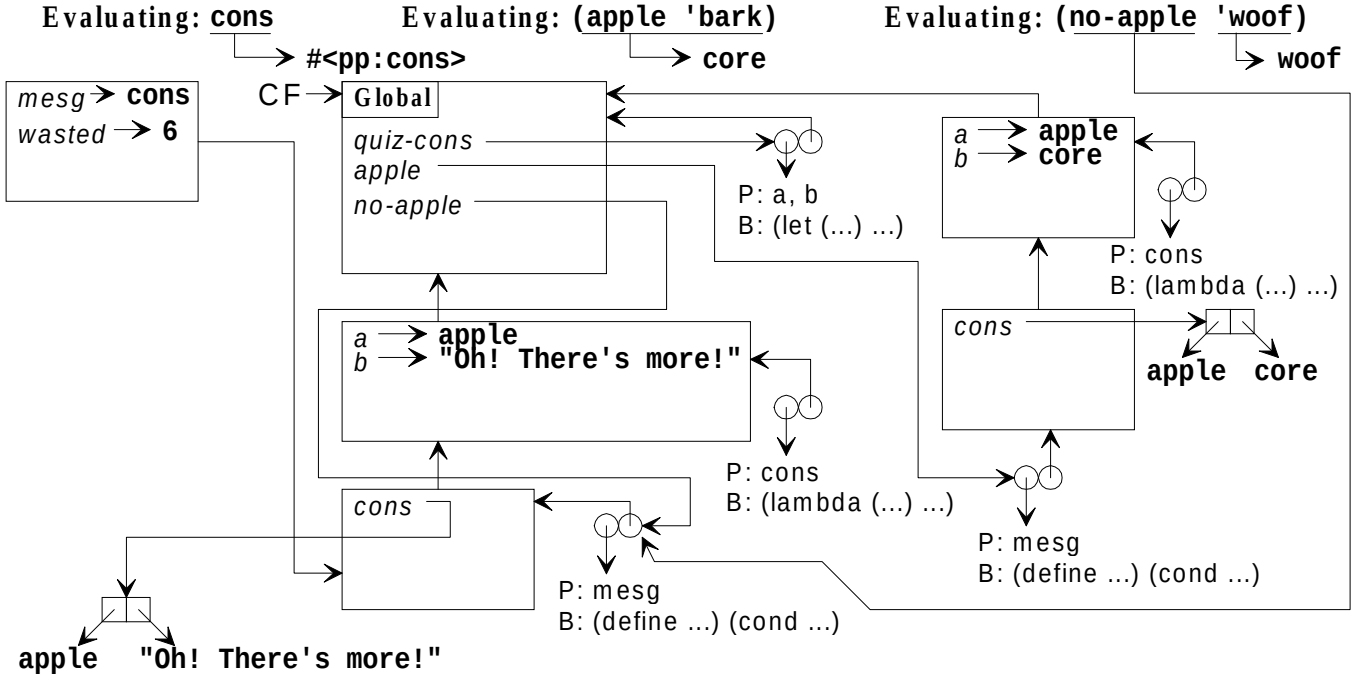
Step 50

Evaluating: (cond ... (b) ...)



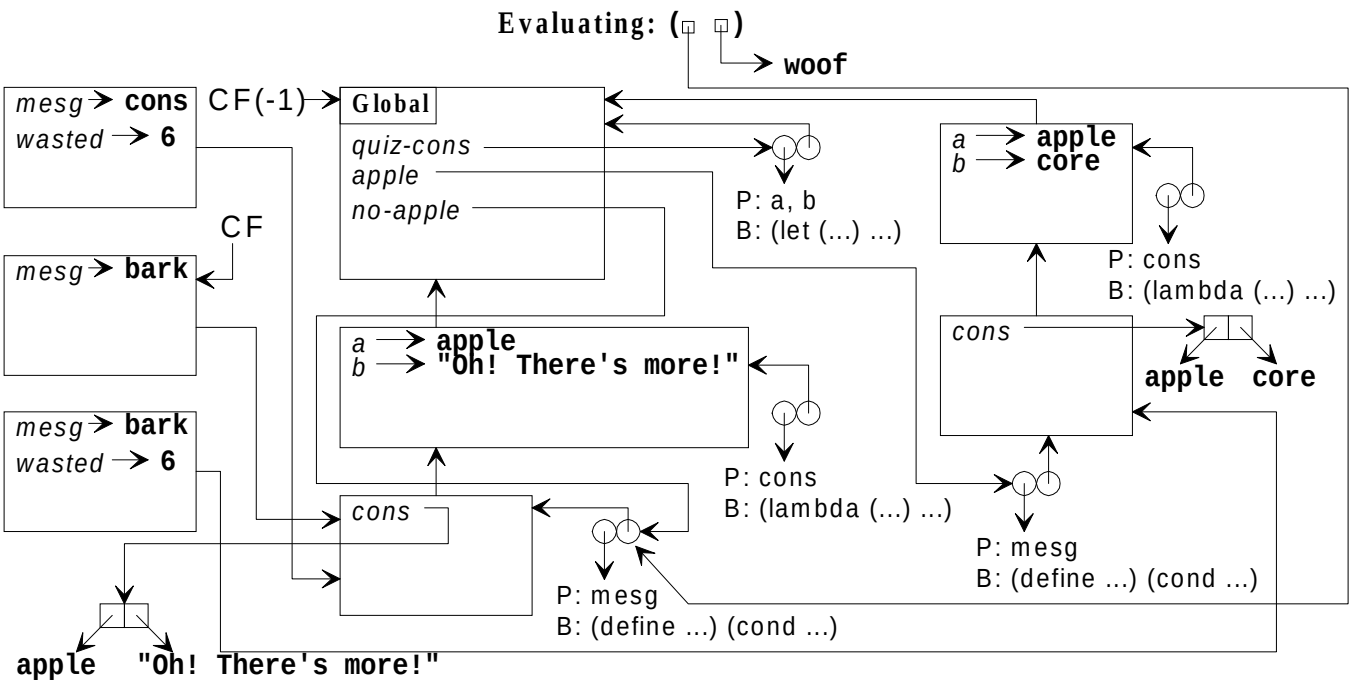
To evaluate the name *b* we look in the Current Frame, don't find it, and then look in the frame pointed to by the Current Frame, and find it is equal to the symbol **core**. Since this is the last expression in the predicate, and the *cond* expression was the last expression in the procedure, the result of the procedure is the result of evaluating the name *b* in the Current Frame, and we move the CF pointer back to the Global Environment and leave the procedure.

Step 51



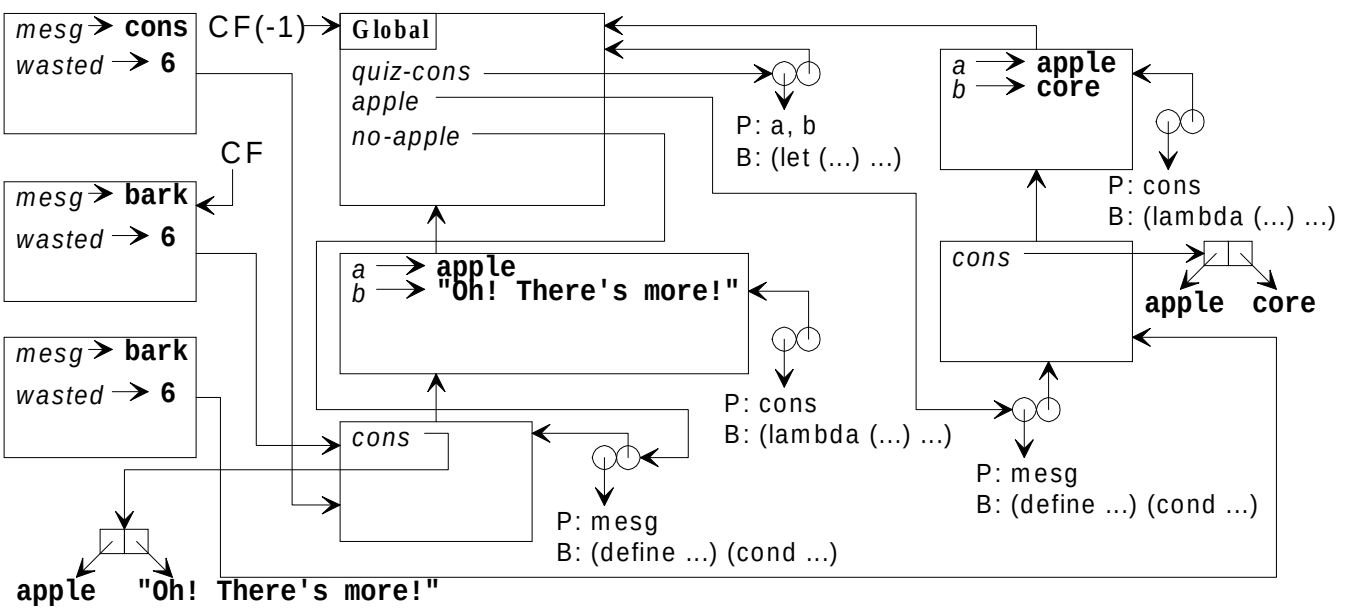
Now we need to evaluate the last expression. The name no-apple evalutes to the procedure it points to, and 'woof evaluates to the symbol wolf.

Step 52



Now that each expression inside this expression has been evaluated, we can evaluate this expression. This is not a special form, the given procedure is applied to the given arguments. This creates a new frame that points to the frame the procedure called points to, and the arguments are bound to the proper parameter names inside the frame. Now the CF pointer is moved and the body of the procedure is evaluated.

Step 53

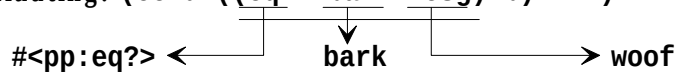


Define is a special form. We must evaluate the expression to find out what the name quiz-cons will point to. The *6* evaluates to the value **6**. This result is then bound to the name *wasted* in the Current Frame.

Step 54

For Steps 55 through 59, refer to the Environment Diagram in Step 54. They all look alike.

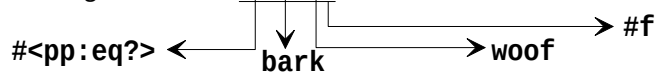
Evaluating: (cond ((eq? 'bark mesg) b) ...)



Cond is a special form, so first we need to evaluate the first conditional expression.
To evaluate it, we need to evaluate all of the parts. The name *eq?* follows the path of pointers to frames from the Current Frame until the Global Environment (since it is undefined in all of the frames inbetween), and is found to be a primitive procedure, **#<pp:eq?>**. *'bark* evaluates to the symbol **bark**. The name *mesg* is found in the Current Frame and evaluates to **woof**.

Step 55

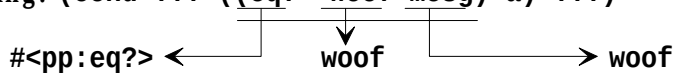
Evaluating: (cond ((□ □ □) b) ...)



Evaluating the primitive procedure **eq?** on the symbols **bark** and **woof** results in **#f** because they are unequal. The result of **#f** in the *cond* expression causes us to move on to the next conditional predicate and evaluate it.

Step 56

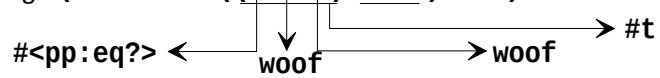
Evaluating: (cond ... ((eq? 'woof mesg) a) ...)



Cond is a special form, so first we need to evaluate the first conditional expression.
To evaluate it, we need to evaluate all of the parts. The name *eq?* follows the path of pointers to frames from the Current Frame until the Global Environment (since it is undefined in all of the frames inbetween), and is found to be a primitive procedure, **#<pp:eq?>**. *'woof* evaluates to the symbol **woof**. The name *mesg* is found in the Current Frame and evaluates to **woof**.

Step 57

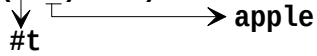
Evaluating: (cond ... ((□ □ □) woof) ...)



Evaluating the primitive procedure **eq?** on the symbols **woof** and **woof** results in **#t** because they are equal. The result of **#t** in the *cond* expression causes us to evaluate the clause associated with this predicate.

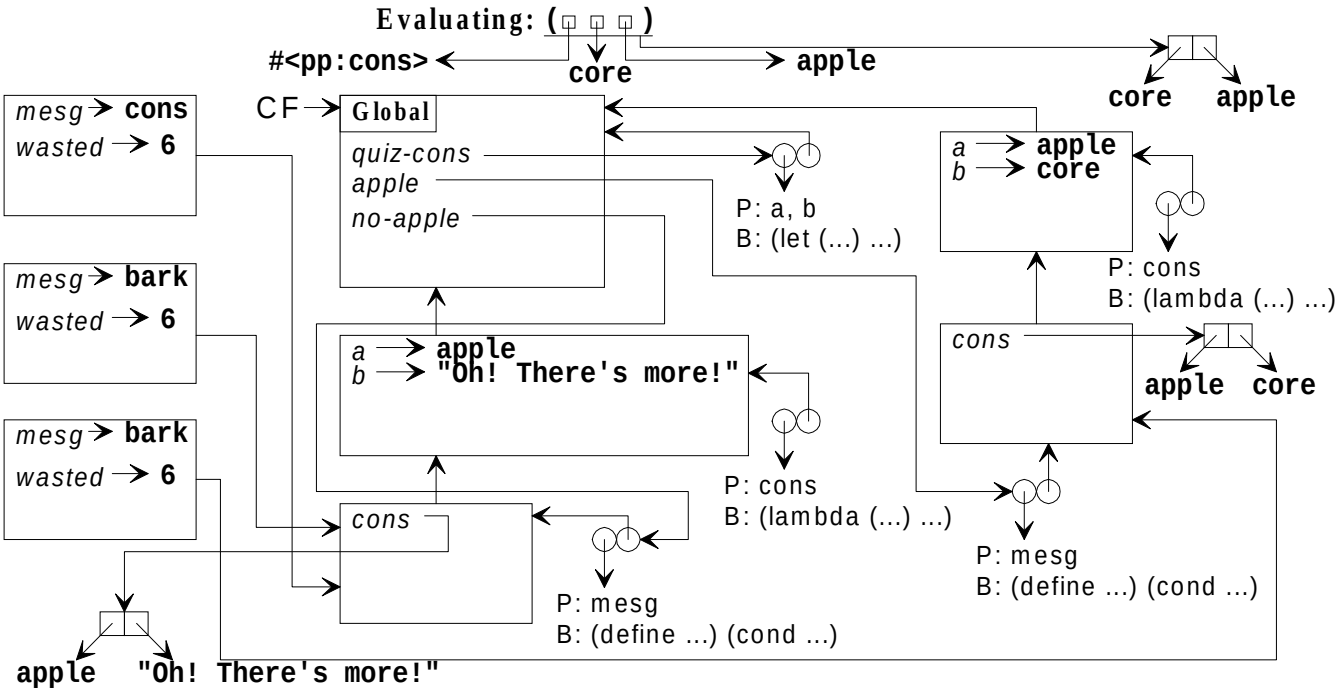
Step 58

Evaluating: (cond ... (□ a) ...)



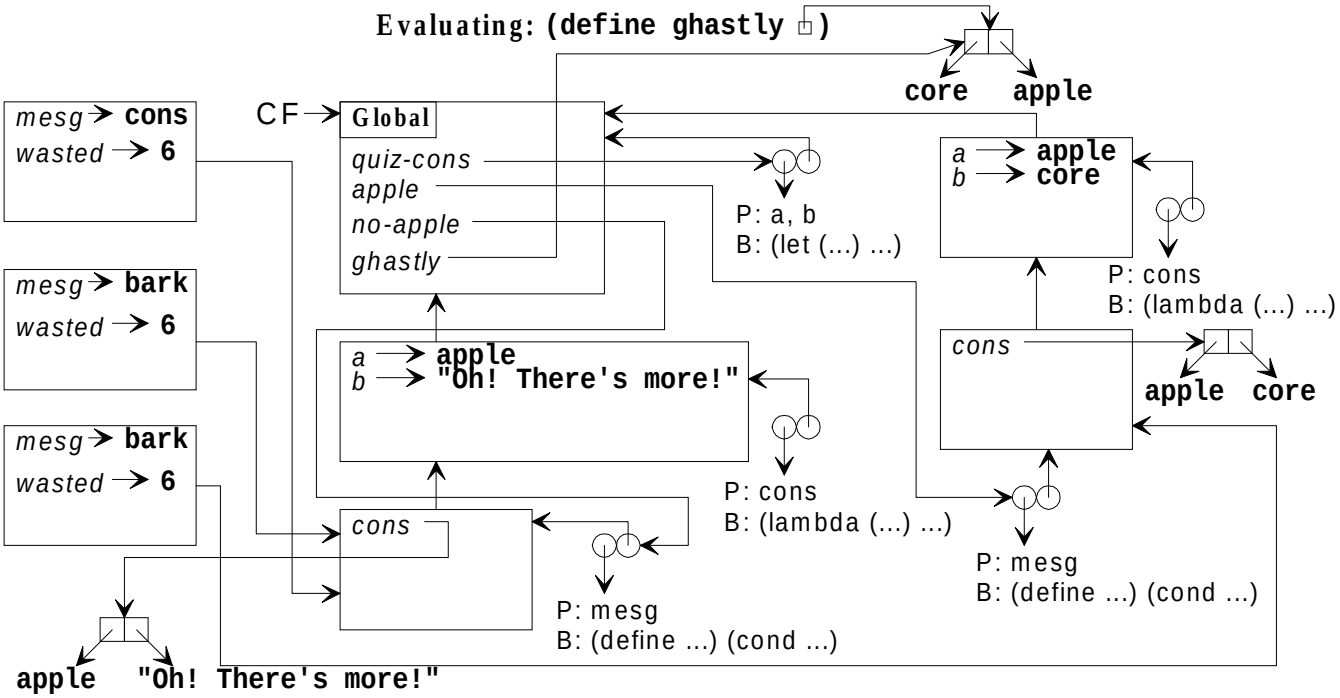
To evaluate the name *a* we look in the Current Frame, don't find it, and then look in the frame pointed to by the Current Frame, and find it is equal to the symbol **apple**. Since this is the last expression in the predicate, and the *cond* expression was the last expression in the procedure, the result of the procedure is the result of evaluating the name *a* in the Current Frame, and we move the CF pointer back to the Global Environment and leave the procedure.

Step 59



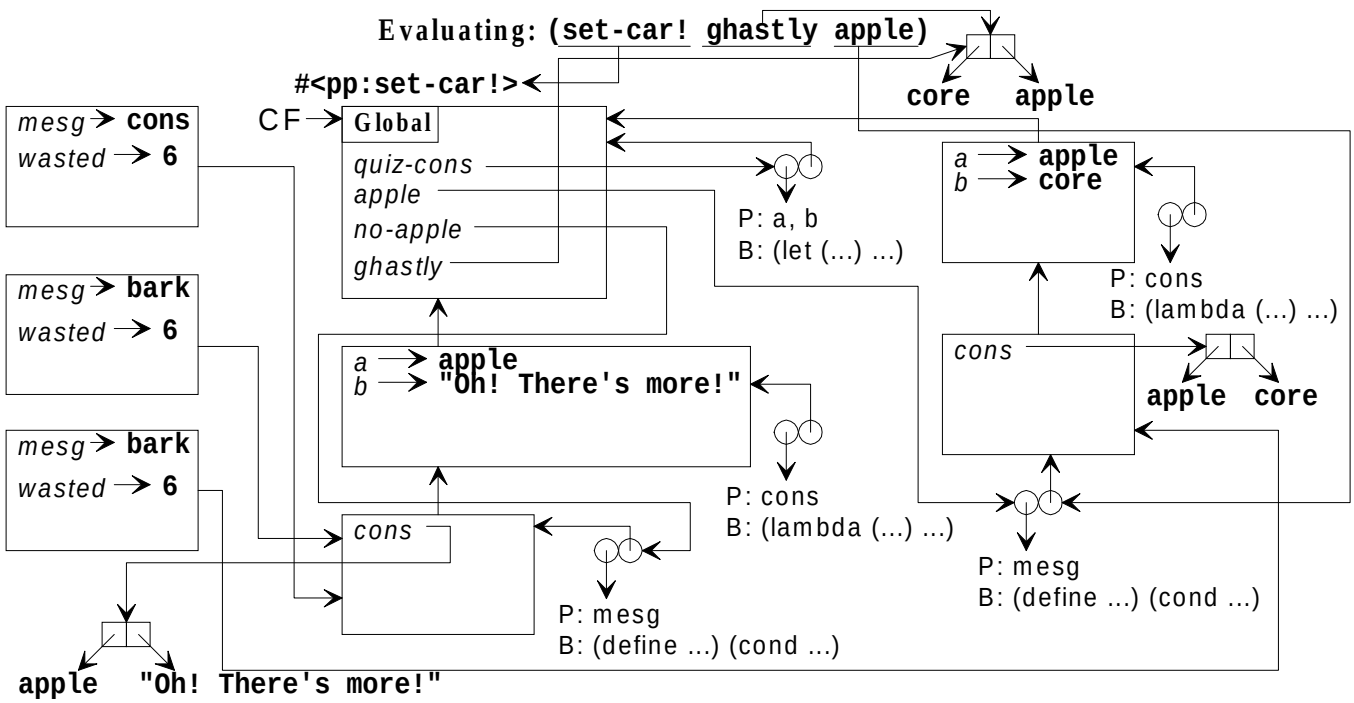
Now that each expression inside this expression has been evaluated, we can evaluate this expression. The primitive procedure *cons* makes a pair who's first argument is the car and the second is the cdr. (Note: no frames are made for primitve procedures.)

Step 60



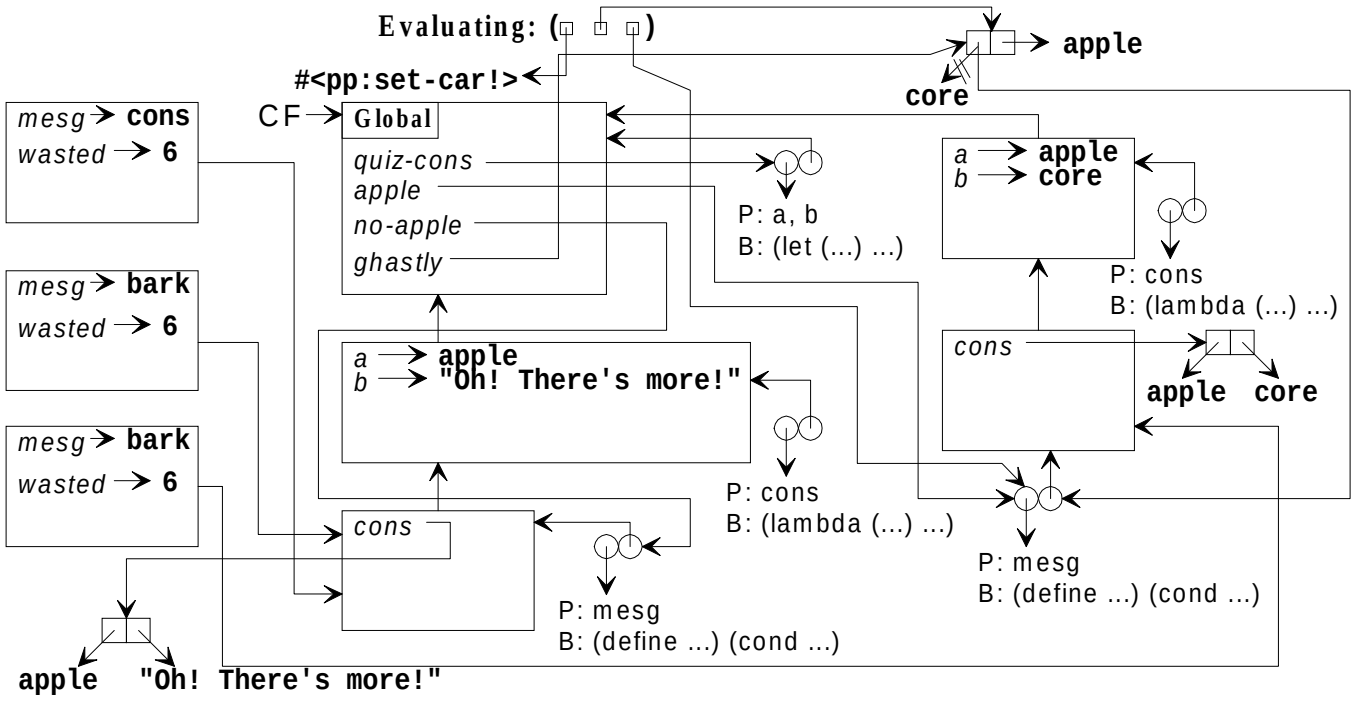
The expression in the *define* special form has been evaluated, now we create the name *ghastly* in the current frame and make it point to the result of the evaluated expression.

Step 61



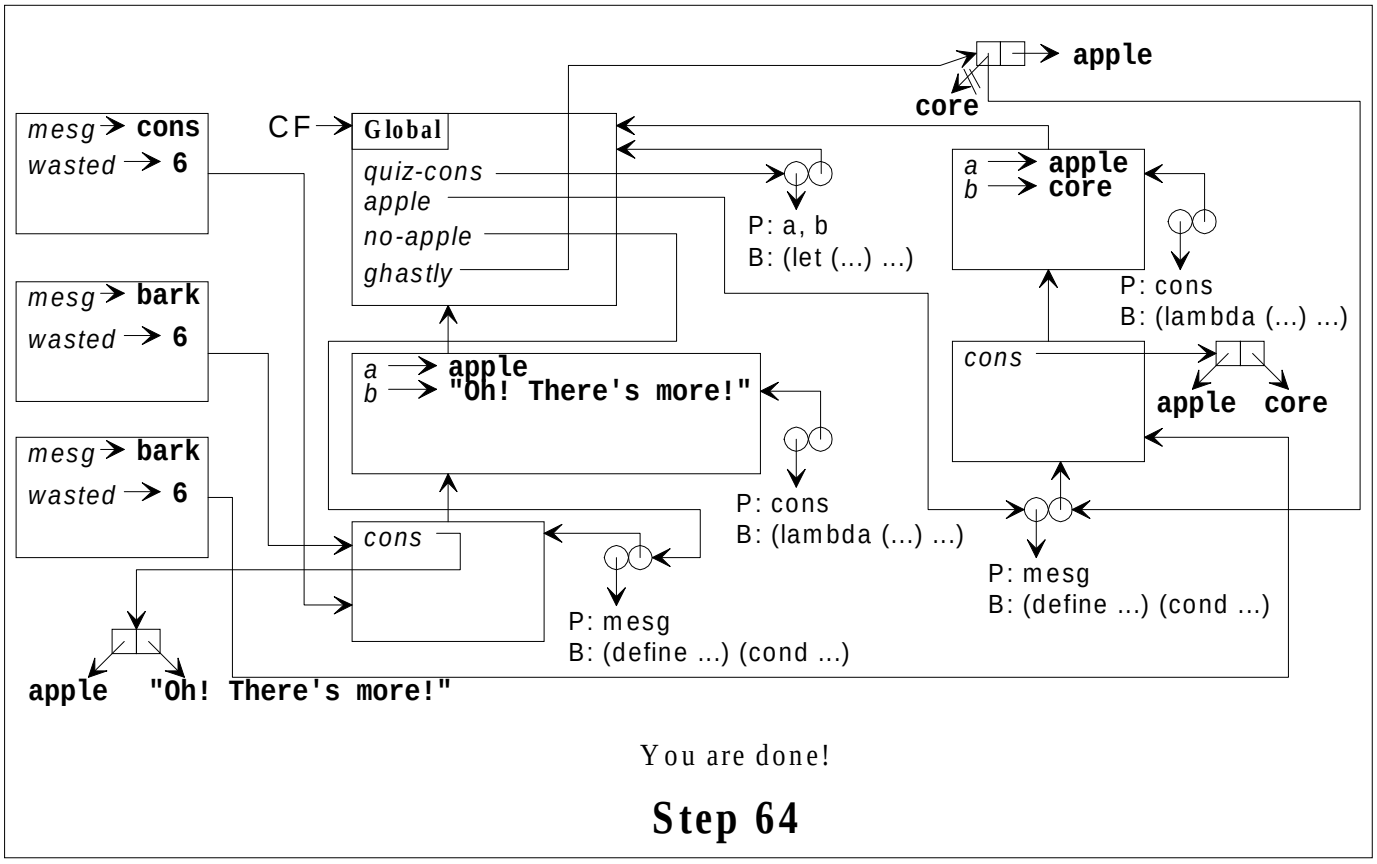
This expression is not a special form, so we must evaluate all of the parts. The name *set-car!* evaluates to the primitive procedure **set-car!**. The name *ghastly* evaluates to the pair it is points to. The name *apple* evaluates to the procedure it points to.

Step 62



Now that all of the expressions within this expression have been evaluated, we finish evaluating the expression. The result of calling the primitive procedure **set-car!**, is to change the *car* of the pair given as the second argument to the thing in the third argument.

Step 63



You are done!

Step 64