The Little Schemer Simplified

Deepak Venkatesh

October 18, 2025

Contents

1	Foreword	4
2	Preface	5
3	Toys 3.1 The Law of car 3.2 The Law of cdr 3.3 The Law of cons 3.4 The Law of null? 3.5 The Law of eq?	7 7 8 8 9 9
4	Do It, Do It Again, and Again, and Again	11
5	Cons the Magnificent	15
6	Numbers Games	23
7	* Oh My Gawd *: It's Full of Stars	24
8	Shadows	25
9	Friends and Relations	26
10	Lambda the Ultimate	27
11	and Again, and Again,	28
12	What Is the Value of All of This?	29
13	Intermission	30

14 The Ten Commandments	31
15 The Five Rules	32

Note:

These are my personal notes created to deepen my understanding of Lisp and programming in general. 'The Little Schemer' (4th edition) by Daniel Friedman and Matthias Felleisen is a remarkable book that teaches programming concepts in a unique and playful way. It builds from first principles using only a small set of primitives, showing how powerful ideas — such as recursion, functional programming, lambda functions, and interpreters — can be expressed using just those few building blocks. I am making this public since other beginners could benefit from these notes.

While the book uses Scheme, I initially worked it out using Common Lisp and had adapted the examples accordingly. Now I am working through it using Racket, a modern descendent of Scheme. Despite its lighthearted tone, the book is far from an easy read — it demands close attention and careful thought. My advice to anyone who wants to learn lisp is to first work through Professor David Touretzky's book titled 'Common Lisp A Gentle Introduction to Symbolic Computing' (2nd ed.). It's a great book for introduction to programming not just Lisp.

All mistakes in these notes, whether typographical or conceptual, are entirely my own. Any misinterpretations are as well. I am still new to both Lisp and programming.

Hardware and Software used for this study

• Language: Racket (a Scheme)

• Editor: Dr Racket

emacs for org notes

• Macbook Pro 2019 2.6 Ghz I7 Intel chip with 16 GB RAM

1 Foreword

By Gerald Sussman of MIT, co-author of the book SICP (the wizard book).

Key Takeaway: In order to be creative one must first gain control of the medium.

- Core skills are the first set of things required to master any pursuit.
- Deep understanding is required to visualize beforehand the program which will be written.
- Lisp provides freedom and flexibility (this is something which will only come in due course of time, as we keep learning more about programming).
- Lisp was initially conceived as a theoretical vehicle for recursion and symbolic algebra (this is the algebra we have been taught in school such as $(a + b)^2 = a^2 + b^2 + 2ab$).
- In Lisp procedures are first class. Procedures are essentially a 'variant' of functions. A mathematical function maps a given input to an output (domain range/co-domain) but a procedure is a process to arrive at the result via computation.
- First Class basically means that the procedure itself can be passed around as arguments to other procedures. Procedures can be return values. They can also be stored in data structures. A similar corollary (though not exact) are composite functions which are usually taught in pre-calculus.
- Lisp programs can manipulate representations of Lisp programs this likely refers to macros and how in Lisp code can be treated as data.

Core Terms/Concepts Learnt

• None

2 Preface

Key Takeaway: The goal of the book is to teach the reader to think recursively.

- Programs take data, apply a process on that data, and then produce some data.
- Recursion is the act of defining an object or solving a problem in terms of itself.
- The authors believe that writing programs recursively in Lisp is essentially pattern recongnition. Well I think it's true for any programming language or any programming paradigm.
- For recursive programming and studying, this book we will need only a few primitives/functions, namely:
 - car
 - cdr
 - cons
 - atom?
 - eq?
 - null?
 - add1, sub1
 - and, or
 - else
 - lambda
 - cond
 - define
- The definitions of the above primitives I am not outlining here and will come to it as we work through the book.
- Authors advise to read this book slowly. Very slowly and delibrately. Re-read it multiple times. Every concept should be clear before going onto the next page.

• In the preface we hit the first difference between Scheme and Common Lisp. () in Scheme is actually different from that in Common Lisp. Scheme considers () as only a list and not an atom. While in Common Lisp () is considered both an atom and a list. ATOM is defined as per the Lisp Hyperspec as well as Common Lisp The Language (2nd ed.) by Guy Steele as 'The predicate ATOM is true if its argument is not a CONS, and otherwise is false. In SBCL, a Common Lisp implementation ATOM will give T

Core Terms/Concepts Learnt

• In Scheme () is only a list and not an atom.

3 Toys

This chapter introduces primitives of Scheme. These are the basic building blocks.

3.1 The Law of car

Key Takeaway: The primitive car is defined only for non-empty lists. The car is the first atom (element) of that list.

- An atom is indivisible number, strings
- Anything enclosed in parenthesis/brackets () is a list.
- We can have nested lists which are also called improper lists and nonnested lists which are proper lists.
- An S-expression which stands for Symbolic Expression is any Lisp object that can be read and evaluated by the Lisp reader.
- Q. How many S-expressions are in the list (how are you doing so far) and what are they? The book answers 6 and those are the elements in the lists, basically the 6 atoms inside the list.
- A question asks how many S-expressions are in the list (((how) are) ((you) (doing so)) far) and gives the answer as 3. It refers to the 3 lists inside the outermost list.
- The difference of () again comes up since it is both a list and an atom in Common Lisp unlike Scheme. The car of () will be NIL in Common Lisp unlike Scheme. In Common Lisp as per the standards and empty list's car and cdr are both NIL (shown below).

```
(car ())
» NIL
```

• car is the first atom/element of a list. If we try to find the car of a string of character or numbers we will get an error like below.

```
> (car 'a)
. . car: contract violation
expected: pair?
given: 'a
> (car 42)
. . car: contract violation
expected: pair?
given: 42
```

3.2 The Law of cdr

Key Takeaway: The primitive cdr is defined only for non-empty lists. The cdr of any non-empty list is always another list.

- The book says car of l is same as (car 1). Similarly for cdr.
- cdr of a single atom/element list is ().
- In Tourtezky's book there is a tool called SDRAW. It allows us to do draw cons cell structures with the car & cdr pointers. I have uploaded the code for this tool on Github here. For (car a) and (cdr a) where a is samosa will be represented as below (doesn't render well in markdown file on github):

```
[*|*]---> NIL
|
|
V
SAMOSA
```

• cdr of an empty list will be () as per Common Lisp standards but in Scheme it is an error.

3.3 The Law of cons

Key Takeaway: The primitive cons takes two arguments. The second argument to cons must be a list. The result is a list.

• cons actually creates a cons cell. The car of which is the first input to cons and the cdr is pointed to the second input. The return value

of the **cons** is a pointer to it. Refer Touretzky's Chapter 2, clearly explained.

• Q. What is (cons s 1) where s is ((a b c)) and 1 is b? This brings in the topic of Dotted Lists. In a proper list the chain of cons cells ends with () as the atom, meaning the last cell points to a NIL but in a dotted list the last atom points to a non NIL atom. In the above case we will get the following:

```
> (cons 'a '(b c))
'(a b c)
> (cons 'a 'b)
'(a . b)
```

3.4 The Law of null?

Key Takeaway: The primitive null? is defined only for lists.

- Q. Is it true that the list 1 is the null list where 1 is ()? Yes, because it is composed of zero S-expressions.
- Another difference in Common Lisp and Scheme is how they refer to False. In scheme it is explicitly #t or #f but in Common Lisp it is T for True or else it is NIL which means False.
- null? of an atom should throw an error for a string or a number but actually it gives #f since in Scheme null? for () is #t and for everything else it is #f. See code below.

```
> (null? 'a)
#f
> (null? (quote ()))
#t
```

3.5 The Law of eq?

Key Takeaway: The primitive eq? in takes two arguments and compares them. Each must be a non numeric atom.

• In eq? the address of the Lisp object is compared. For instance if we create two cons cells with same elements eq? will give #f

```
> (eq? (cons 'a 'b) (cons 'a 'b)) #f
```

Core Terms/Concepts Learnt

- car, cdr, cons, eq?, null?, quote / ', #t, #f,
- Atoms, S-Expressions, Lists, Dotted Lists

4 Do It, Do It Again, and Again, and Again ...

This chapter explains recursion. The best material for recursion in my opinion is Chapter 8 in Touretzky's book.

Key Takeaway: The First Commandment (preliminary): Always ask null? as the first question in expressing a function

- After reading Touretzky's chapter on recursion this chapter will feel very easy. Also the first commandment is not really true always. Sometimes in recursion the first question is not necessarily null?. Later in the book the authors do add in this nuance.
- The chapter introduces a function named lat?. It stands for a list of atoms. This means every element of the list is an atom. It can be written as below.

```
(define lat?
  (lambda (l)
     (cond
          ((null? l) #t)
          ((atom? (car l)) (lat? (cdr l)))
          (else #f))))
```

- It is important to understand how cond functions. Well cond is actually a macro. This macro has a series of tests and results. The macro goes from top to bottom. The cases are processed from left to right under each test. Technically we can have more than one result per test for evaluation. As a Lisp 'trick' the last test is usually an else which evaluates to #t always and hence the last result is returned. cond is a very nice way to implement If..then..Else. I have never seen such seamless conditional in any language yet.
- lat? basically is a cond which keeps checking through all the elements of a list to test for atom? till the list ends. It checks car one by one for each subsequent cdr for atom?.
- I would study Chapter 8 of Touretzky for getting the intuition on recursion right. The author has done a great job.

• Dr Racket comes with an inbuilt tool called **trace** in the library package called ~(racket/trace) which lets us see the actual function calls. So lets trace all the recursive examples in this chapter.

```
> (lat? '(Jack Sprat could eat no chicken fat))
>(lat? '(Jack Sprat could eat no chicken fat))
>(lat? '(Sprat could eat no chicken fat))
>(lat? '(could eat no chicken fat))
>(lat? '(eat no chicken fat))
>(lat? '(no chicken fat))
>(lat? '(chicken fat))
>(lat? '(fat))
>(lat? '(fat))
```

• Another example which has a nested list

```
> (lat? '(Jack (Sprat could) eat no chicken fat))
>(lat? '(Jack (Sprat could) eat no chicken fat))
>(lat? '((Sprat could) eat no chicken fat))
<#f
#f</pre>
```

• Few more examples from the chapter using trace

```
> (lat? '(bacon and eggs))
>(lat? '(bacon and eggs))
>(lat? '(and eggs))
>(lat? '(eggs))
>(lat? '())
<#t
#t

> (lat? '(bacon (and eggs)))
>(lat? '(bacon (and eggs)))
>(lat? '((and eggs)))
```

```
<#f
#f
```

- or is introduced as a logical operator. or asks two questions, one at a time. If the first one is true it stops answers true. Otherwise it asks the second question and answers with whatever the second question answers.
- member? is a function which returns a #t if the input is one of the elements in a list else #f. The book defines this function using or whereas it is actually not necessary.

• The application of member? to find out whether meat is in the list (mashed potatoes and meat gravy) would generate this recursive call

```
> (member? 'meat '(mashed potatoes and meat gravy))
>(member? 'meat '(mashed potatoes and meat gravy))
>(member? 'meat '(potatoes and meat gravy))
>(member? 'meat '(and meat gravy))
>(member? 'meat '(meat gravy))
<#t
#t</pre>
```

• Another example

```
> (member? 'liver '(bagels and lox))
>(member? 'liver '(bagels and lox))
>(member? 'liver '(and lox))
>(member? 'liver '(lox))
>(member? 'liver '())
<#f
#f</pre>
```

Core Terms/Concepts Learnt

- or
- Basic template of recursion. Chapter 8 of Touretzky is great for a deeper dive into ways to construct recursion. Also tail optimized recursion is to be studied from the book 'Sketchy Scheme' by Nils M Holm.

5 Cons the Magnificent

This chapter explains the methods to build lists using cons recursively.

Key Takeaway: The Second Commandment: Use cons to build lists The Third Commandment: When building a list, describe the first typical element, and then cons it onto the natural recursion The Fourth Commandement: Always change at lest one argument while recurring. It must be changed to be closer to termination. The changing argument must be tested in the termination condition: when using cdr, test termination with null?

- In last chapter we made a member? function and in this chapter we will be making a function which will *remove* a member
- The first attempt to build the **rember** function fails since it removes all the initial elements before finding the one it wants to remove. The authors have nicely demonstrated why **cons** is required to define this function.
- The way to write rember is as below. Also note as per Scheme semantics there is no? at the end of rember because it is actually not a predicate.

• There is a way to contrast the incorrect rember with the correct cons rember by looking at the recursive trace calls. The incorrect rember-wrong is below with its trace and return.

```
((eq? (car lat) a) #t)
        (else (rember-wrong a (cdr lat))))))
  > (rember-wrong 'and '(bacon lettuce and tomato))
  >(rember-wrong 'and '(bacon lettuce and tomato))
  >(rember-wrong 'and '(lettuce and tomato))
  >(rember-wrong 'and '(and tomato))
  <'(tomato)
  '(tomato)
  Whereas the correct trace and output is as below
  > (rember 'and '(bacon lettuce and tomato))
  >(rember 'and '(bacon lettuce and tomato))
  > (rember 'and '(lettuce and tomato))
  > >(rember 'and '(and tomato))
  < <'(tomato)
  < '(lettuce tomato)
  <'(bacon lettuce tomato)
  '(bacon lettuce tomato)
  Another example
  > (rember 'sauce '(soy sauce and tomato sauce))
  >(rember 'sauce '(soy sauce and tomato sauce))
  > (rember 'sauce '(sauce and tomato sauce))
  < '(and tomato sauce)
  <'(soy and tomato sauce)
  '(soy and tomato sauce)
• Next function is firsts to build a list of the first S-expressions in
  nested lists. The code and trace is
      (define firsts
        (lambda (l)
          (cond
```

((null? 1) (quote ()))

```
(else (cons (car (car 1))
                         (firsts (cdr 1))))))
  >(firsts
    '((apple peach pumpkin)
      (plum pear cherry)
      (grape raisin pea)
      (bean carrot eggplant)))
  > (firsts '((plum pear cherry) (grape raisin pea) (bean carrot eggplant)))
  > >(firsts '((grape raisin pea) (bean carrot eggplant)))
  > > (firsts '((bean carrot eggplant)))
  > > >(firsts '())
  < < <'()
  < < '(bean)
  < <'(grape bean)
  < '(plum grape bean)
  <'(apple plum grape bean)
  '(apple plum grape bean)
• The book refers to seconds but doesn't provide code for it. But I will
  try it out anyways.
      (define seconds
        (lambda (l)
          (cond ((null? 1) (quote ()))
                (else (cons (car (cdr (car 1)))
                             (seconds (cdr 1)))))))
  >(seconds '((a b) (c d) (e f)))
  > (seconds '((c d) (e f)))
  > >(seconds '((e f)))
  > > (seconds '())
  < < '()
  < <'(f)
```

• In the recursion technique of cons-ing cells the last cons cells' cdr

< '(d f) <'(b d f) '(b d f) pointer will point to a nil or an empty list (). Therefore, the usual terminal or base condition is to check for null? then cons a ().

- Although the book alludes to the fact that the cons-ing can be in any direction the trace in Dr Racket actually shows the cons-ing with a < or a >. So a () gets cons-ed with the last recurring item and goes back to the first item. In the above example () is cons-ed to f to make a list (f). This (f) is then cons-ed to d to make the list (d f). This (d f) is then cons-ed to b to finally get (b d f).
- Without looking into the questions was able to build these cons-es for insertR, insertL, and subst.

```
(define insertR
  (lambda (new old lat)
        (cond ((null? lat) (quote ()))
              ((eq? old (car lat)) (cons (car lat) (cons new (cdr lat))))
              (else (cons (car lat) (insertR new old (cdr lat)))))))

(define insertL
  (lambda (new old lat)
        (cond ((null? lat) (quote ()))
              ((eq? old (car lat)) (cons new (cons (car lat) (cdr lat))))
              (else (cons (car lat) (insertL new old (cdr lat)))))))

(define subst
  (lambda (new old lat)
        (cond ((null? lat) (quote ()))
              ((eq? old (car lat)) (cons new (cdr lat)))
              (else (cons (car lat) (subst new old (cdr lat)))))))
```

• subst2 is another function defined in the book, it substitutes either the first occurrence of one thing or another.

• subst2 involves an or but a better example could be used such as below. Since trace will give a better view.

```
(define subst2
      (lambda (new o1 o2 lat)
        (cond ((null? lat) (quote ()))
              ((or (eq? (car lat) o1) (eq? (car lat) o2)) (cons new (cdr lat)))
              (else (cons (car lat) (subst2 new o1 o2 (cdr lat)))))))
> (subst2 'vanilla 'chocolate 'banana
          '(caramel raspberry ice cream with
                    chocolate topping with some bananas))
>(subst2
  'vanilla
  'chocolate
  '(caramel raspberry ice cream with chocolate topping with some bananas))
> (subst2
   'vanilla
   'chocolate
   'banana
   '(raspberry ice cream with chocolate topping with some bananas))
> >(subst2
    'vanilla
    'chocolate
    'banana
    '(ice cream with chocolate topping with some bananas))
> > (subst2
     'vanilla
     'chocolate
     '(cream with chocolate topping with some bananas))
> > (subst2
      'vanilla
      'chocolate
      'banana
      '(with chocolate topping with some bananas))
> > > (subst2
       'vanilla
       'chocolate
```

```
'banana
'(chocolate topping with some bananas))

< < '(vanilla topping with some bananas)

< < '(with vanilla topping with some bananas)

< '(cream with vanilla topping with some bananas)

< '(ice cream with vanilla topping with some bananas)

< '(raspberry ice cream with vanilla topping with some bananas)

<'(caramel raspberry ice cream with vanilla topping with some bananas)

'(caramel raspberry ice cream with vanilla topping with some bananas)
```

• multirember is below. I am unsure why two else is used by the author. Probably I will learn it down the line. But the trace captures the series of recursive steps beautifully. Note the > and < they capture the stack trace nicely.

```
(define multirember
      (lambda (a lat)
        (cond ((null? lat) (quote ()))
              ((eq? (car lat) a) (multirember a (cdr lat)))
              (else (cons (car lat) (multirember a (cdr lat)))))))
> (multirember 'cup '(coffee cup tea cup and hick cup))
>(multirember 'cup '(coffee cup tea cup and hick cup))
> (multirember 'cup '(cup tea cup and hick cup))
> (multirember 'cup '(tea cup and hick cup))
> >(multirember 'cup '(cup and hick cup))
> >(multirember 'cup '(and hick cup))
> > (multirember 'cup '(hick cup))
> > > (multirember 'cup '(cup))
> > > (multirember 'cup '())
< < < ()
< < '(hick)
< <'(and hick)
< '(tea and hick)
<'(coffee tea and hick)
'(coffee tea and hick)
```

• Function definition for other 'multi' variants below: multiinsertR, multiinsertL, and multisubst.

```
(define multiinsertR
      (lambda (new old lat)
        (cond ((null? lat) (quote ()))
              ((eq? old (car lat))
               (cons (car lat)(cons new (multiinsertR new old (cdr lat)))))
              (else (cons (car lat) (multiinsertR new old (cdr lat)))))))
> (multiinsertR 'bag 'cup '(coffee cup tea cup and hick cup))
>(multiinsertR 'bag 'cup '(coffee cup tea cup and hick cup))
> (multiinsertR 'bag 'cup '(cup tea cup and hick cup))
> >(multiinsertR 'bag 'cup '(tea cup and hick cup))
> > (multiinsertR 'bag 'cup '(cup and hick cup))
> > >(multiinsertR 'bag 'cup '(and hick cup))
>> > (multiinsertR 'bag 'cup '(hick cup))
>>> (multiinsertR 'bag 'cup '(cup))
>>> (multiinsertR 'bag 'cup '())
< < < < '()
< < < '(cup bag)
< < < '(hick cup bag)
< < <'(and hick cup bag)
< < '(cup bag and hick cup bag)
< <'(tea cup bag and hick cup bag)
< '(cup bag tea cup bag and hick cup bag)
<'(coffee cup bag tea cup bag and hick cup bag)</pre>
'(coffee cup bag tea cup bag and hick cup bag)
    (define multiinsertL
      (lambda (new old lat)
        (cond ((null? lat) (quote ()))
              ((eq? old (car lat))
               (cons new (cons (car lat) (multiinsertL new old (cdr lat)))))
              (else (cons (car lat) (multiinsertL new old (cdr lat))))))
    > (multiinsertL 'bag 'cup '(coffee cup tea cup and hick cup))
>(multiinsertL 'bag 'cup '(coffee cup tea cup and hick cup))
> (multiinsertL 'bag 'cup '(cup tea cup and hick cup))
> >(multiinsertL 'bag 'cup '(tea cup and hick cup))
> > (multiinsertL 'bag 'cup '(cup and hick cup))
> > >(multiinsertL 'bag 'cup '(and hick cup))
```

```
> > > (multiinsertL 'bag 'cup '(hick cup))
>>> (multiinsertL 'bag 'cup '(cup))
>>> (multiinsertL 'bag 'cup '())
< < < < '()
< < < '(bag cup)
< < < '(hick bag cup)
< < <'(and hick bag cup)
< < '(bag cup and hick bag cup)
< <'(tea bag cup and hick bag cup)
< '(bag cup tea bag cup and hick bag cup)
<'(coffee bag cup tea bag cup and hick bag cup)</pre>
'(coffee bag cup tea bag cup and hick bag cup)
    (define multisubst
      (lambda (new old lat)
        (cond ((null? lat) (quote ()))
              ((eq? (car lat) old) (cons new (multisubst new old (cdr lat))))
              (else (cons (car lat) (multisubst new old (cdr lat)))))))
> (multisubst 'bag 'cup '(coffee cup tea cup and hick cup))
>(multisubst 'bag 'cup '(coffee cup tea cup and hick cup))
> (multisubst 'bag 'cup '(cup tea cup and hick cup))
> >(multisubst 'bag 'cup '(tea cup and hick cup))
> > (multisubst 'bag 'cup '(cup and hick cup))
> > >(multisubst 'bag 'cup '(and hick cup))
> > > (multisubst 'bag 'cup '(hick cup))
>> > (multisubst 'bag 'cup '(cup))
>>> (multisubst 'bag 'cup '())
< < < < '()
< < < '(bag)
< < < '(hick bag)
< < < (and hick bag)
< < '(bag and hick bag)
< <'(tea bag and hick bag)
< '(bag tea bag and hick bag)
<'(coffee bag tea bag and hick bag)</pre>
'(coffee bag tea bag and hick bag)
```

6 Numbers Games

7 * Oh My Gawd *: It's Full of Stars

8 Shadows

9 Friends and Relations

10 Lambda the Ultimate

11 ... and Again, and Again, and Again, ...

12 What Is the Value of All of This?

13 Intermission

14 The Ten Commandments

15 The Five Rules