

# programming essentials with Scheme

and a three-fold  
Zen for Scheme

To follow along,  
install [Guile](#) and  
try the examples  
as you read.

Wisp

No map of  
No scheme

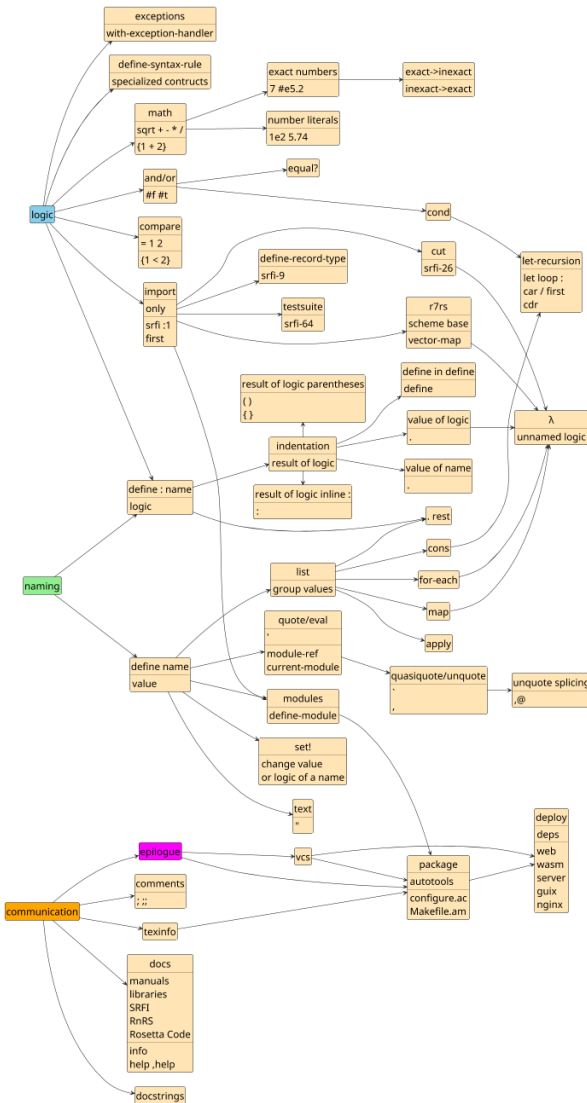

Logic — define : name

naming — define name

Symbols —

— " —

— " —



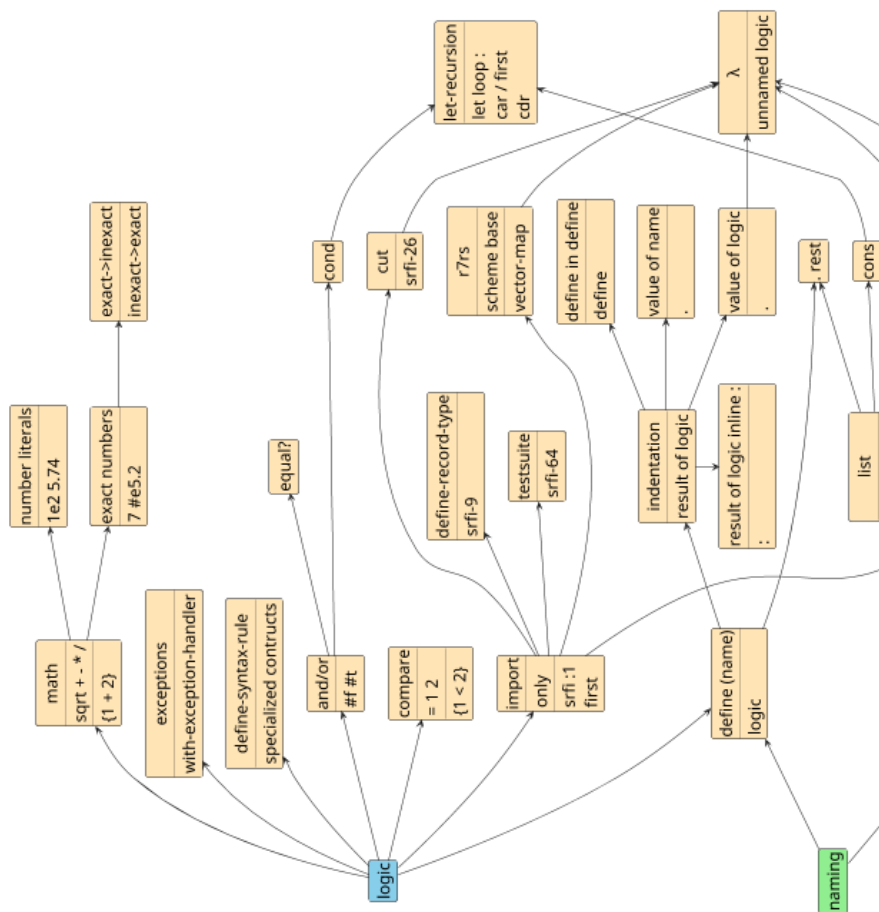
# Contents

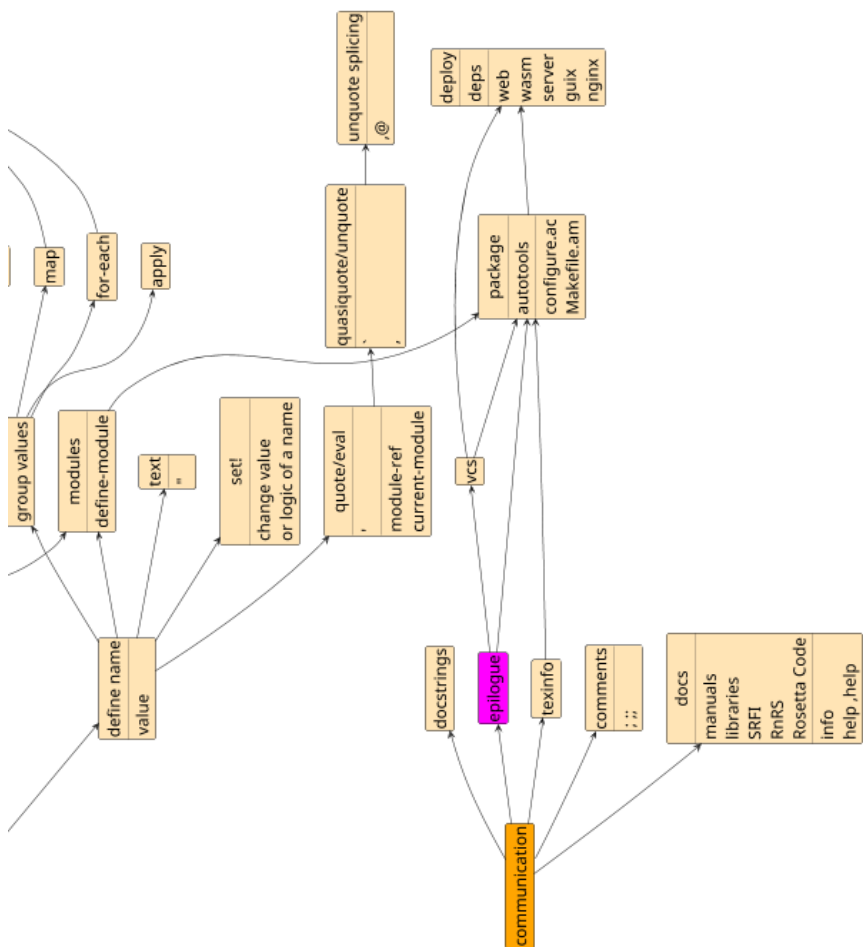
i	The Map of Scheme	5
ii	Preface	7
1	Name a value: <code>define</code>	8
2	Compare numbers	9
3	Use infix in logic	10
4	Use named values in logic	11
5	Add comments with <code>;</code>	11
6	Logic with <code>true</code> and <code>false</code>	12
7	Name the result of logic with indentation	13
8	Name logic with <code>define</code> <code>(</code>	14
9	Name a name with <code>define</code>	15
10	Return the value of logic	15
11	Name in <code>define</code> <code>(</code> with <code>define</code>	16
12	Return a list of values with <code>list</code>	17
13	Name the result of logic in one line with <code>()</code>	18
14	Name text with <code>"</code>	19
15	Take decisions with <code>cond</code>	20
16	Use fine-grained numbers with <code>number-literals</code>	21

17 Use exact numbers with #e and quotients	21
18 See inexact value of exact number with exact->inexact	22
19 Use math with the usual operators as logic	23
20 Compare structural values with equal?	24
21 Apply logic to a list of values with apply	25
22 Get the arguments of named logic as list with . args	26
23 Change the value or logic of a defined name with set!	27
24 Apply logic to each value in lists and ignoring the results with for-each	27
25 Get the result of applying logic to each value in lists with map	28
26 Create nameless logic with lambda	29
27 Reuse your logic with let-recursion	30
28 Import pre-defined named logic and values with import	32
29 Extend a list with cons	34
30 Apply partial procedures with srfi :26 cut	35
31 Use r7rs datatypes, e.g. with vector-map	36
32 Name structured values with define-record-type	37
33 Create your own modules with define-module	38
34 Handle errors with-exception-handler	40

35 Test your code with <code>srfi 64</code>	41
36 Define derived logic structures with <code>define-syntax-rule</code>	42
37 Get and resolve names used in code with <code>quote</code> , <code>eval</code> , and <code>module-ref</code>	44
38 Build value-lists with <code>quasiquote</code> and <code>unquote</code>	46
39 Merge lists with <code>append</code> or <code>unquote-splicing</code>	50
40 Document procedures with <code>docstrings</code>	51
41 Read the docs	52
42 Create a manual as package documentation with <code>texinfo</code>	53
43 Track changes with a version tracking system like <code>Mercurial</code> or <code>Git</code>	55
44 Package with <code>autoconf</code> and <code>automake</code>	56
44.1 Init a project with <code>hall</code> . . . . .	62
45 Deploy a project to users	63

# i The Map of Scheme





## ii Preface

**Why this book?** Providing a concise start, a no-frills, opinionated intro to programming from first **define** to deploying an application on just 64 short pages.

**Who is it for?** You are a newcomer and want to **learn by trying code examples**? You know programming and want **a running start** into Scheme? You want to see how little suffices with Scheme’s practical minimalism? Then this book is for you.

**What is Scheme?** Scheme is a programming language — a Lisp — that follows principle *“design not by piling feature on top of feature, but by removing the weaknesses and restrictions that make additional features appear necessary”*. This book uses Guile Scheme, the official extension language of the GNU project.

**How to get Guile?** Download and install Guile from the website [www.gnu.org/software/guile](http://www.gnu.org/software/guile) — then open the REPL by executing `guile` in the terminal. The REPL is where you type and try code interactively. On some platforms you need to use `guile3.0`.

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# 1 Name a value: define

Use `(define ...)` to name a value. Return the last name.

---

```
(define small-tree-height-meters 3)
(define large-tree-height-meters 5)
small-tree-height-meters
```

---

After typing or copying a block into the Guile REPL, **hit enter**. You should then see

```
$1 = 3
```

This means: the first returned value (`$1`) is 3. The next time you return a value, it will be called `$2`.

Names can contain any letter except for (white-)space, quote, comma or parentheses. They must not be numbers.

---

```
(define illegal name 1)
(define 'illegal-name 2)
(define ,illegal-name 3)
(define illegal)name 4)
(define 1113841 5)
```

---

---

While executing meta-command:

Syntax error:

unknown location: `source` expression failed to match any  
↪ pattern `in` form `(define illegal name 1)`

While reading expression:

```
#<unknown port>:14:2: unexpected ")"
scheme@(guile-user)>
```

---



## 2 Compare numbers

---

```
(= 3 3)
```

---

#t

---

```
(= 3 5)
```

---

#f

#t means true, #f means false. Parentheses return the result of logic. The logic comes first. This is clear for =, but easy to misread for <.

---

```
(< 3 5) ;; is 3 smaller than 5? #true
```

---

#t

---

```
(> 5 3) ;; is 5 bigger than 3? #true
```

---

#t

---

```
(> 3 3) ;; is 3 bigger than 3? #false
```

---

#f

---

```
(>= 3 3) ;; is 3 bigger or equal to 3? #true
```

---

#t

---

```
(<= 3 3) ;; is 3 bigger or equal to 3? #true
```

---

#t

### 3 Use infix in logic

---

```
#!curly-infix
{3 = 5}
```

---

```
#f
```

---

```
#!curly-infix
{3 < 5}
```

---

```
#t
```

Infix logic directly gives a value. To use it, you must put `#!curly-infix` somewhere in your code before you use the first curly brace (`{...}`).

Because infix-logic gives a value, you can use it in place of a value, for example to nest or name it:

---

```
#!curly-infix
{{5 < 3} equal? #f}
```

---

```
#t
```

---

```
#!curly-infix
(define is-math-sane? {3 < 5})
is-math-sane?
```

---

```
#t
```

By convention, names that have the value `true` or `false` have the suffix `?`.

## 4 Use named values in logic

---

```
#!curly-infix
(define small-tree-height/m 3)
(define large-tree-height/m 5)
{small-tree-height/m < large-tree-height/m}
```

---

#t

## 5 Add comments with ;

---

```
(define birch-height/m 3)
;; this is a comment
(define height ;; comment at the end
  ;; comment between lines
  birch-height/m)
height
```

---

3

It is common to use `;;` instead of `;`, but not required.

A comment goes from the first `;` to the end of the line.

## 6 Logic with true and false

---

```
(and #t #t)
```

---

```
#t
```

---

```
(and #f #t)
```

---

```
#f
```

---

```
(or #f #t)
```

---

```
#t
```

---

```
(or #f #f)
```

---

```
#f
```

If any value passed to `and` is `#f` (`#false`), it ignores further values.  
If any value passed to `or` is not `#f` (not `#false`), it ignores further values.

---

```
#!curly-infix
(and #t #t #t) ;; => #true
(and #t #f #t) ;; => #false
(and {3 < 5} {5 < 3}) ;; => #false
(or #t #f #t) ;; => true
(or {3 < 5} {5 < 3}) ;; => #true
(or #f #f #f) ;; => #false
```

---

For `and` and `or`, everything is `#true` (`#t`) except for `#false` (`#f`). Given the number of hard to trace errors in other languages that turn up in production, this is the only sane policy.

## 7 Name the result of logic with indentation

---

```
#!curly-infix
(define birch-h/m 3)
(define chestnut-h/m 5)
(define same-héight?
  (= birch-h/m chestnut-h/m))
(define smaller?
  {birch-h/m < chestnut-h/m}) ;; infix
smaller?
```

---

#t

The infix gives a value, so it directly returns its value. Here this value is then named `smaller?`.

## 8 Name logic with define (

---

```
(define (same-height? tree-height-a tree-height-b)
  (= tree-height-a tree-height-b))
(same-height? 3 3)
```

---

#t

By convention, logic that returns true or false has the suffix ?.

You can now use your named logic like all other logic. Even with infix.

---

```
#!curly-infix
(define (same-height? tree-height-a tree-height-b)
  (= tree-height-a tree-height-b))
{3 same-height? 3}
```

---

#t

What this map of Scheme calls *named logic* is commonly called **function** or **procedure**. We'll stick with *logic* for the sake of a leaner conceptual mapping.

The indented lines with the logic named here are called the **body**.

## 9 Name a name with define

---

```
(define small-tree-height-meters 3)
(define height
  small-tree-height-meters)
height
```

---

3

## 10 Return the value of logic

---

```
#!curly-infix
(define (larger-than-4? size)
  {size > 4})
larger-than-4?
```

---

```
#<procedure larger-than-4? (size)>
```

The value of logic defined with `define` ( is a **procedure**. You can see the arguments in the output: If you call it with too few or too many arguments, you get errors.

There are other kinds of logic: syntax rules and reader-macros. We will cover syntax rules later. New reader macros are rarely needed; using `{...}` for infix math is a reader macro activated with `#!curly-infix`.

## 11 Name in define ( with define

---

```
#!curly-infix
(define birch-h/m 3)
(define (birch-is-small)
  (define reference-h/m 4)
  {birch-h/m < reference-h/m})
(birch-is-small)
```

---

#t

Only the last part of the body of **define** ( is returned.

A calculation inside parentheses or curly braces is executed in-place, so when it is the last element, its result value is returned.



Zen for Scheme

### A Zen for Scheme part 1: Birds Eye

**RR** Remove limitations to Reduce the feature-count you need,  
*but OM: Optimizability Matters.*

**FI** Freedom for the Implementations and from Implementations,  
*but CM: Community Matters: Join the one you choose.*

**SL** Mind the Small systems!  
And the Large systems!

**ES** Errors should never pass silently,  
*unless speed is set higher than safety.*

*Thanks for the error-handling principle goes to John Cowan.*



## 12 Return a list of values with list

---

```
(define known-heights
  (list 3 3.75 5 100))
(list (list 3 5)
      known-heights)
```

---

```
((3 5) (3 3.75 5 100))
```

You can put values on their own lines. Different from `define` (, list keeps all values, not just the last.

---

```
(define known-heights-2
  (list 3
        3.75 5
        100)) ;; list keeps all numbers
(define known-heights-3
  (list
    3
    3.75
    5
    100))
(define (last-height)
  3 3.75 5 100) ;; (define (...) ...) only returns 100
(= 100 (last-height))
```

---

#t

## 13 Name the result of logic in one line with ()

---

```
(define birch-h/m 3)
(define chestnut-h/m 5)

(define same-height (= birch-h/m chestnut-h/m))
same-height
```

---

#f

This is consistent with infix-math and uniform with defining logic:

---

```
#!curly-infix
(define birch-h/m 3)
(define chestnut-h/m 5)

(define same-height {birch-h/m = chestnut-h/m})

(define (same-height? tree-height-a tree-height-b)
  (= tree-height-a tree-height-b))
(define same-height2 (same-height? birch-h/m
  ↪ chestnut-h/m))
(list same-height same-height2)
```

---

'(#f #f)

## 14 Name text with "

---

```
(define tree-description "large tree")
(define footer "In Love,

Arne")
(define greeting
  "Hello")
(display footer)
```

---

In Love,

Arne

Like { }, text (called **string** as in “string of characters”) is its value.

Text can span multiple lines. Linebreaks in text do not affect the meaning of code.

You can use `\n` to add a line break within text without having a visual line break. The backslash (`\`) is the escape character and `\n` represents a line break. To type a real `\` within quotes ( " ), you must escape it as `\\`.

With `display` you can show text as it will look in an editor.

Text is stronger than comments, unless it is inside a comment:

---

```
(define with-comment ;; belongs to coment
  ;; comment "quotes inside comment"
  "Hello ;; part of the text")
with-comment
```

---

Hello ;; part of the text

## 15 Take decisions with cond

---

```
#!curly-infix
(define chestnut-h/m 5)
(define tree-description
  (cond
    ({chestnut-h/m > 4}
     "large tree")
    ((= 4 chestnut-h/m)
     "four meter tree")
    (else
     "small tree")))
tree-description
```

---

large tree

`cond` checks its clauses one by one and uses the first with *value* `#true`. To `cond`, every valid value is `#true` (`#t`) except for `#false` (`#f`). To use named logic, enclose it in parentheses to check its *value*.

---

```
#!curly-infix
(list
  (cond
    (5 #t)
    (else ;; else is #true in cond
     #f))
  (cond (#f #f)
        (else #t))
  (cond
    ({3 < 5} #t)
    (else #f)))
```

---

'(#t #t #t)

## 16 Use fine-grained numbers with number-literals

---

```
(define more-precise-height 5.32517)
(define 100-meters 1e2)
(list more-precise-height
      100-meters)
```

---

```
(5.32517 100.0)
```

These are floating point numbers. They store approximate values in 64 bit binary, depending on the platform. Read all the details in the Guile Reference manual [Real and Rational Numbers](#), the [r5rs numbers](#), and [IEEE 754](#).<sup>1</sup>

## 17 Use exact numbers with #e and quotients

---

```
(define exactly-1/5 #e0.2)
(define exactly-1/5-too 1/5)
(list exactly-1/5
      exactly-1/5-too)
```

---

```
(1/5 1/5)
```

Guile computations with exact numbers stay reasonably fast even for unreasonably large or small numbers.

---

<sup>1</sup>All links are listed on page [68](#).

## 18 See inexact value of exact number with exact->inexact

---

```
(list (exact->inexact #e0.2)
      (exact->inexact 1/5)
      (exact->inexact 2e7))
```

---

(0.2 0.2 2.0e7)

The inverse is inexact->exact:

---

```
(inexact->exact 0.5)
```

---

1/2

Note that a regular 0.2 need not be exactly 1/5, because floating point numbers do not have exact representation for that. You'll need #e to have precise 0.2.

---

```
(list (inexact->exact 0.2)
      #e0.2)
```

---

(3602879701896397/18014398509481984 1/5)

## 19 Use math with the usual operators as logic

---

```
(define one-hundred
  (* 10 10))
(define half-hundred (/ one-hundred 2))
half-hundred
```

---

50

Remember that names cannot be valid numbers!

---

```
(define 100 ;; error!
  (* 10 10))
```

---

---

```
ice-9/boot-9.scm:1685:16: In procedure raise-exception:
Syntax error:
unknown location: source expression failed to match any
↪ pattern in form (define 100 (* 10 10))
```

Entering a new prompt. Type ``,bt'` for a backtrace or  
↪ ``,q'` to continue.  
scheme@(guile-user) [1]>

---

## 20 Compare structural values with equal?

---

```
;; reuse name definition snippets from  
;; Return list of values with =list=  
{{{known-heights}}}   
{{{known-heights2}}}   
(equal? known-heights known-heights-2 known-heights-3)
```

---

#t

Like = and +, `equal?` can be used on arbitrary numbers of values.

*Reusing the snippets from **Return list of values with list** uses **noweb** syntax via Emacs Org Mode.*

**Zen for Scheme**

### A Zen for Scheme part 2: On the Ground

**HA** Hygiene reduces Anxiety,  
*except where it blocks your path.*

**PP** Practicality beats Purity,  
*except where it leads into a dead end.*

**3P** 3 Pillars of improvement:  
Experimentation, Implementation, Standardization.



## 21 Apply logic to a list of values with `apply`

---

```
(apply = (list 3 3))
```

---

#t

---

```
(equal?  
  (= 3 3)  
  (apply =  
    (list 3 3)))
```

---

#t

Only the last argument of `apply` is treated as list, so you can give initial arguments:

---

```
(define a 1)  
(define b 1)  
(apply = a b  
  (list 1 1)) ;; becomes (= a b 1 1)
```

---

#t

## 22 Get the arguments of named logic as list with `. args`

---

```
(define (same? heights)
  (apply = heights))
(define (same2? . heights)
  (apply = heights))
(list (same? (list 1 1 1))
      (same2? 1 1 1))
```

---

```
'(#t #t)
```

These are called **rest**. Getting them is not for efficiency: the list creation is implicit. You can mix regular arguments and **rest** arguments:

---

```
(define (same? alice bob . rest)
  (display (list alice bob rest))
  (newline)
  (apply = alice bob rest))
(display (same? 1 1 1 1))
```

---

```
(1 1 (1 1))
```

```
#t
```

Remember that `apply` uses only the last of its arguments as list, in symmetry with `. rest`.

## 23 Change the value or logic of a defined name with `set!`

---

```
(define birch-h/m 3)
(set! birch-h/m 3.74)
birch-h/m
```

---

3.74

It is customary to suffix named logic that changes values of existing names with `!`.

Since logic can cause changes to names and not just return a result, it is not called `function`, but `procedure` in documentation; `proc` for brevity.

## 24 Apply logic to each value in lists and ignoring the results with `for-each`

---

```
#!curly-infix
(define birch-h/m 3)
(define has-birch-height #f)
(define (set-true-if-birch-height! height/m)
  (cond
    ({birch-h/m = height/m}
     (set! has-birch-height #t))))
(define heights (list 3 3.75 5 100))
(for-each set-true-if-birch-height! heights)
has-birch-height
```

---

#t

## 25 Get the result of applying logic to each value in lists with `map`

---

```
(define birch-h/m 3)
(define (same-height-as-birch? height/m)
  (= birch-h/m height/m))
(define heights (list 3 3.75 5 100))
(list heights
  (map same-height-as-birch?
    heights)
  (map + ;; becomes 1+3 2+2 3+1
    (list 1 2 3)
    (list 3 2 1))
  (map list
    (list 1 2 3)
    (list 3 2 1)))
```

---

```
'((3 3.75 5 100) (#t #f #f #f) (4 4 4) ((1 3) (2 2) (3 1)))
```

When operating on multiple lists, `map` takes one argument from each list. All lists must be the same length. *To remember: `apply` extracts the values from its *last argument*, `map` extracts one value from *each argument* after the first. `apply map list ...` flips columns and rows:*

---

```
(apply map list
  (list (list 1 2 3)
    (list 3 2 1)))
```

---

```
((1 3) (2 2) (3 1))
```

## 26 Create nameless logic with lambda

---

```
(define (is-same-height? a b)
  (> a b)) ;; <- this is a mistake
(display is-same-height?)
(newline) ; (newline) prints a linebreak
(display (is-same-height? 3 3))(newline)
(define (fixed a b)
  (= a b))
(set! is-same-height? fixed)
(display is-same-height?)(newline) ;; now called "fixed"
(display (is-same-height? 3 3))(newline)
;; shorter and avoiding name pollution and confusion.
(set! is-same-height?
  (lambda (a b)
    (= a b))) ;; must be on a new line
               ;; to not be part of the arguments.
;; since lambda has no name, we see the original name
(display is-same-height?)(newline)
(display (is-same-height? 3 3))
```

---

```
#<procedure is-same-height? (a b)>
#f
#<procedure fixed (a b)>
#t
#<procedure is-same-height? (a b)>
#t
```

The return value of `lambda` is logic (a procedure).

If logic is defined via `define` (, it knows the name it has been defined as. With `lambda`, it does not know the name.

`lambda` is a special form. Think of it as

`(define (name arguments) ...)`, but without the name.

## 27 Reuse your logic with let-recursion

Remember the for-each example:

---

```
#!curly-infix
(define has-birch-height #f)
(define heights (list 3 3.75 5 100))
(define (set-true-if-birch-height! height/m)
  (define birch-h/m 3)
  (cond
    ({birch-h/m = height/m}
     (set! has-birch-height #t))))
(for-each set-true-if-birch-height! heights)
has-birch-height
```

---

#t

Instead of for-each, we can build our own iteration:

---

```
(define heights (list 3 3.75 5 100))
(define (has-birch-height? heights)
  (define birch-h/m 3)
  (let loop ((heights heights)) ;; start with value
    → heights
    (cond
      ((null? heights) #f) ;; if heights is empty: #false
      ((= birch-h/m (car heights)) ;; car returns is first
       #t)
      (else
       ;; continue with all but the first
       (loop (cdr heights))))))
(has-birch-height? heights)
```

---

#t

`null?` asks whether the list is empty. `car` gets the first element of a list, `cdr` gets the list without its first element.

Recursion is usually easier to debug (all variable elements are available at the top of the let recursion) and often creates cleaner APIs than iteration, because fewer names are visible from outside.

As rule of thumb: start with the recursion end condition (here: `(null? heights)`) and ensure that each branch of the `cond` either ends recursion by returning something (here `#f` or `#t`) or moves a step towards finishing (usually with `cdr`).

*Another example why **recursion wins**:*

---

```
(define (fib n)
  (let rek ((i 0) (u 1) (v 1))
    (if (>= i (- n 2))
        v
        (rek (+ i 1) v (+ u v)))))
```

---

**Zen for Scheme**

### A Zen for Scheme part 3: Submerged in Code

- WM** Use the Weakest Method that gets the job done,  
*but know the stronger methods to employ them as needed.*
- RW** Recursion Wins,  
*except where a loop-macro is better.*
- RM** Readability matters,  
*and nesting works.*

## 28 Import pre-defined named logic and values with import

---

```
(import (ice-9 pretty-print)
        (srfi :1 lists))

(pretty-print
 (list 12
       (list 34)
       5 6))
(pretty-print (list
 (first (list 1 2 3)) ;; 1
 (second (list 1 2 3)) ;; 2
 (third (list 1 2 3)) ;; 3

 (member 2 (list 1 2 3)))) ;; list 2 3 => #true
```

---

```
(12 (34) 5 6)
(1 2 3 (2 3))
```

Import uses modules which can have multiple components. In the first import, `ice-9` is one component and the second is `pretty-print`. In the second, `srfi` is the first component, `:1` is the second, and `lists` is the third.

`ice-9` is the name for the core extensions of Guile. It's a play of words on [ice-nine](#), a fictional perfect seed crystal.

SRFI's are Scheme Requests For Implementation, portable libraries built in collaboration between different Scheme implementations. The ones available in Guile can be found [in the Guile Reference manual](#). More can be found on [srfi.schemers.org](http://srfi.schemers.org). They are imported by number (`:1`) and can have a third component with a name, but that's not required.



You can use `only` to import only specific names.

---

```
(import (only (srfi :1) first second) ;; no third
        (only (srfi :1) iota))

(first (list 1 2 3)) ;; 1
(second (list 1 2 3)) ;; 2
(third (list 1 2 3)) ;; error: third not imported
(iota 5) ;; list 0 1 2 3 4
```

---

---

```
ice-9/boot-9.scm:1685:16: In procedure raise-exception:
Unbound variable: third
```

```
Entering a new prompt.  Type `,bt' for a backtrace or
↪ `,q' to continue.
scheme@(guile-user) [1]>
```

---

## 29 Extend a list with cons

*The core of composing elementwise operations.*

To build your own `map` function which returns a list of results, you need to add to a list.

---

```
(cons 1 (list 2 3))  
;; => list 1 2 3
```

---

1 2 3

Used for a simplified `map` implementation that takes a single list:

---

```
(import (only (srfi :1) first))  
(define (single-map proc elements)  
  (let loop ((changed (list)) (elements elements))  
    (cond  
      ((null? elements)  
       (reverse changed))  
      (else  
       (loop  
         ;; add processed first element to changed  
         (cons (proc (first elements))  
               changed)  
         ;; drop first element from elements  
         (cdr elements))))))  
(single-map even? (list 1 2 3))  
;; => #f #t #f
```

---

```
'(#f #t #f)
```

## 30 Apply partial procedures with `srfi :26 cut`

---

```
(import (srfi :26 cut))

(define (plus-3 number)
  (+ 3 number))
(define plus-3-cut (cut + 3 <>))

(list
  (map plus-3
    (list 1 2 3)) ;; list 4 5 6

  (map (cut + 3 <>)
    (list 1 2 3)) ;; list 4 5 6

  (map (cut - <> 1) ;; => <> - 1
    (list 1 2 3)) ;; list 0 1 2

  (map (cut - 1 <>) ;; => 1 - <>
    (list 1 2 3)) ;; list 0 -1 -2

  (map plus-3-cut
    (list 1 2 3))) ;; list 4 5 6
```

---

((4 5 6) (4 5 6) (0 1 2) (0 -1 -2) (4 5 6))

`cut` enables more concise definition of derived logic.

## 31 Use `r7rs` datatypes, e.g. with `vector-map`

R<sup>7</sup>RS is the 7th [Revised Report on Scheme](#). Guile provides a superset of the standard: its core can be imported as `scheme base`. A foundational datatype is [Vectors](#) with  $O(1)$  random access guarantee.

---

```
(import (scheme base))
(define vec (list->vector '(1 b "third")))
(vector-map (lambda (element) (cons 'el element))
            vec)
```

---

```
#((el . 1) (el . b) (el . "third"))
```

Vectors have the literal form `#(a b c)`. It is an error to mutate these.

---

```
(import (scheme base))
(define mutable-vector (list->vector '(1 b "third")))
(define literal-vector #(1 b "third"))
(vector-set! mutable-vector 1 "bee") ;; allowed
; (vector-set! literal-vector 1 "bee") ;; forbidden
(list mutable-vector literal-vector)
```

---

---

```
'(#(1 "bee" "third") #(1 b "third"))
```

---

## 32 Name structured values with define-record-type

---

```
(import (srfi :9 records))

(define-record-type <tree>
  (make-tree type height-m weight-kg carbon-kg)
  tree?
  (type tree-type)
  (height-m tree-height)
  (weight-kg tree-weight)
  (carbon-kg tree-carbon))

(define birch-young
  (make-tree "birch" 13 90 45)) ;; 10 year, 10cm diameter,
(define birch-old
  (make-tree "birch" 30 5301 2650)) ;; 50 year, 50cm
(define birch-weights
  (map tree-weight (list birch-young birch-old)))
(list birch-young
      birch-old
      birch-weights)
```

---

---

```
'(#<<tree> type: "birch" height-m: 13 weight-kg: 90
  ↪ carbon-kg: 45> #<<tree> type: "birch" height-m: 30
  ↪ weight-kg: 5301 carbon-kg: 2650> (90 5301))
```

---

Carbon content in birch trees is about 46% to 50.6% of the mass. See [forestry commission technical paper 1993](#).

Height from [Waldwissen](#), weight from [BaumUndErde](#).

## 33 Create your own modules with define-module

To provide your own module, create a file named by the module name. For (import (example trees)) the file must be `example/trees.scm`. Use `define-module` and `#:export` what gets imported:

---

```
(define-module (example trees)
  #:export
  (birch-young
    make-tree tree? tree-carbon))
(import (srfi :9 records)) ;; imports after module
(define-record-type <tree> ;; reduced
  (make-tree carbon-kg)
  tree?
  (carbon-kg tree-carbon))
(define birch-young
  (make-tree 45)) ;; 10 year, 10cm diameter,
```

---

To use that module, add your root folder to the search path. Then just import it. To ensure that the file is run that way, use shell-indirection:

---

```
#!/usr/bin/env bash
exec -a "${0}" guile \
  -L "$(dirname "${0}")" "$@"
;; !# Guile execution
(import (example trees))
birch-young
```

---

While compiling expression:

no code for module (example trees)

ice-9/boot-9.scm:1683:22: In procedure raise-exception:

Unbound variable: birch-young

Entering a new prompt. Type ``,bt'` for a backtrace or ``,q'` to conti

Make executable with `chmod +x the-file.w`, run with `./the-file.w`

## 34 Handle errors with-exception-handler

---

```
;; unhandled exception stops execution
(define (add-5 input)
  (display (+ 5 input))) ;; illegal for text
;; (map add-5 '("five" 6 "seven")) ;; error: Wrong type
↪ argument
;; check inputs
(define (add-5-if input)
  (if (number? input)
      (display (+ 5 input))
      #f))
(map add-5-if '("five" 6 "seven"))
```

---

11

---

```
;; handle exceptions
(define (add-5-handler input)
  (with-exception-handler
    (λ (e) (format #t "must be number, is ~S.\n" input)
              #f)
    (λ () (display (+ 5 input))(newline))
    #:unwind? #t)) ;; #t: continue #f: stop
(map add-5-handler '("five" 6 "seven"))
```

---

must be number, is "five".

11

must be number, is "seven".

In Guile Scheme checking inputs is often cheaper than exception handling. Format replaces patterns (here: `~s`) in text with values (here `input`).



## 35 Test your code with `srfi 64`

Is your code correct?

---

```
(import (srfi :64 testsuite))

(define (tree-carbon weight-kg)
  (* 0.5 weight-kg))

(define (run-tests)
  (test-begin "test-tree-carbon")
  (test-equal 45.0
    (tree-carbon 90))
  (test-approximate 45.0
    (+ 40 (random 10.0))
    5) ;; expected error size
  (test-assert (equal? 45.0 (tree-carbon 90)))
  (test-error (throw 'wrong-value))
  (test-end "test-tree-carbon"))

(run-tests)
```

---

```
%%% Starting test test-tree-carbon (Writing full log to "test-tree-carbon.log")
# of expected passes          4
```

You can use this anywhere.

For details, see [srfi 64](#).

## 36 Define derived logic structures with define-syntax-rule

In usual logic application in **procedures**, arguments are evaluated to their return value first. **Procedures** evaluate from **inside to outside**:

---

```
(import (ice-9 pretty-print))
(define (hello-printer . args)
  (pretty-print "Hello")
  (for-each pretty-print args))
(hello-printer 1 (pretty-print "second") ;; evaluated
↪ first
                               3 4)
;; prints "second" "Hello" 1 3 4
```

---

```
"second"
"Hello"
1
#<unspecified>
3
4
```

(pretty-print "second") is evaluated before being passed to hello-printer, so its result is shown first.

But for example **cond** only evaluates the required branches. It is not a **procedure**, but a **syntax-rule**.

Syntax-rules evaluate from **outside to inside**:

---

```
(import (ice-9 pretty-print))
(define-syntax-rule (early-printer args ...)
  (begin
    (pretty-print "Hello")
    (for-each pretty-print (list args ...))))
(early-printer 1 (pretty-print "second")
               3 4)
;; prints "Hello" "second" 1 3 4
```

---

```
"Hello"
"second"
1
#<unspecified>
3
4
```

Arguments of `define-syntax-rule` are only evaluated when they are passed into a regular `procedure` or returned. By calling other `syntax-rules` in `syntax-rules`, evaluation can be delayed further.

`define-syntax-rule` can reorder arguments and pass them to other `syntax-rules` and to `procedures`. It cannot ask for argument values, because it does not evaluate names as values. It operates on names and structure.

Instead of `(define (name . args) args)`, it uses a pattern:

```
(define-syntax-rule (name args ...) args ...)
```

The ellipsis `...` marks `args` as standing for zero or more names. It must be used with the ellipsis.

The body of `define-syntax-rule` must only have one element. The logic `begin` wraps its own body to count as only one element. It returns the value of the last element in its body.

## 37 Get and resolve names used in code with quote, eval, and module-ref

---

```
(list (quote alice)
      'bob ;; shorthand for (quote bob)
      'carol
      (quote dave))
;; => (alice bob carol dave)

(define alice "the first")

(eval 'alice (current-module))
;; => "the first"
(module-ref (current-module) 'alice)
;; => "the first"
;; module-ref is less powerful than eval. And safer.

(define code
  (quote
    (list 1 2 3)))
code
;; => (list 1 2 3)
;; uses parentheses form
(eval code (current-module))
;; => (1 2 3)

'(1 2 3)
;; (1 2 3)
(list 1 2 3)
;; (1 2 3)

(equal? '(1 2 3)
        (list 1 2 3))
```

---

The form `'(1 2 3)` is a shorthand to create an **immutable** ([literal](#)) list that is `equal?` to list `1 2 3`.

But some operations like `list-set!` `the-list` `index` `new-value` from `srfi :1` do not work on immutable lists.

---

```
(define mutable-list (list 1 2 3))
(display mutable-list)
(newline)
(list-set! mutable-list 1 'a) ;; zero-indexed
(display mutable-list)
```

---

---

```
(1 2 3)
(1 a 3)
```

---

---

```
(define immutable-list '(1 2 3))
(display immutable-list)
(list-set! immutable-list 1 'a) ;; error!
```

---

---

```
ice-9/boot-9.scm:1685:16: In procedure raise-exception:
In procedure set-car!: Wrong type argument in position 1
↪ (expecting mutable pair): (2 3)
```

Entering a new prompt. Type ``,bt'` for a backtrace or  
↪ ``,q'` to **continue**.  
`scheme@(guile-user) [1]>`

---

```
#+endSRC
```

## 38 Build value-lists with quasiquote and unquote

---

```
(define (tree-manual type height weight carbon-content)
  "Create a tree with list and cons."
  (list (cons 'type type)
        (cons 'height height)
        (cons 'weight weight)
        (cons 'carbon-content carbon-content)))
(display (tree-manual "birch" 13 90 45))(newline)

(define (tree-quasiquote type height weight
                        carbon-content)
  "Create a tree with raw quasiquote and unquote."
  (quasiquote
    ((type . (unquote type))
     (height . (unquote height))
     (weight . (unquote weight))
     (carbon-content . (unquote carbon-content)))))
(display (tree-quasiquote "birch" 13 90 45))(newline)

(define (tree-shorthand type height weight carbon-content)
  "Create a tree with quasiquote/unquote shorthands."
  `((type . ,type) ;; ` is short for quasiquoted list
    (height . ,height) ;; , is short for unquote
    (weight . ,weight)
    (carbon-content . ,carbon-content)))
(display (tree-shorthand "birch" 13 90 45))
```

---

```
((type . birch) (height . 13) (weight . 90)
 → (carbon-content . 45))
((type . birch) (height . 13) (weight . 90)
 → (carbon-content . 45))
```

---

```
((type . birch) (height . 13) (weight . 90)  
↪ (carbon-content . 45))
```

---

These three methods are almost equivalent, except that quasiquoting can create an immutable list, but does not have to.

---

```
(define three 3)
(define mutable-list (list 1 2 3))
(list-set! mutable-list 1 'a) ;; zero-indexed
mutable-list
```

---

---

```
(1 a 3)
```

---

---

```
(define immutable-list `(1 2 3))
(list-set! immutable-list 1 'a) ;; error!
immutable-list
```

---

---

```
ice-9/boot-9.scm:1685:16: In procedure raise-exception:
In procedure set-car!: Wrong type argument in position 1
→ (expecting mutable pair): (2 3)
```

Entering a new prompt. Type ``,bt'` for a backtrace or  
→ ``,q'` to continue.  
scheme@(guile-user) [1]>

---

---

```
(define three 3)
(define mutable-quasiquoted `(1 2 ,three))
(list-set! mutable-quasiquoted 1 'a) ;; no error yet!
mutable-quasiquoted
```

---

---

```
(1 a 3)
```

---

Mutating quasiquoted lists may throw an error in the future. [From the standard](#) (r7rs):



A quasiquote expression may return either newly allocated, mutable objects or literal structure for any structure that is constructed at run time ...

## 39 Merge lists with append or unquote-splicing

---

```
(import (ice-9 pretty-print))
(define birch-carbon/kg '(5000 5301 5500))
(define oak-carbon/kg '(7000 7700 8000))
;; append merges lists
(pretty-print
 (append birch-carbon/kg
         oak-carbon/kg))
;; unquote-splicing splices a list into quasiquote (`)
(pretty-print
 `((unquote-splicing birch-carbon/kg)
   (unquote-splicing oak-carbon/kg)))
;; with shorthand ,@
(pretty-print
 `(@birch-carbon/kg
   @oak-carbon/kg))
```

---

(5000 5301 5500 7000 7700 8000)

(5000 5301 5500 7000 7700 8000)

(5000 5301 5500 7000 7700 8000)

Unquote splicing can also insert the result of logic:

---

```
`(@map 1- '(1 2 3))
 ,@map 1+ (reverse '(1 2)))
 (unquote-splicing (list 1 0)))
```

---

(0 1 2 3 2 1 0)

## 40 Document procedures with docstrings

---

```
(define (documented-proc arg)
  "Proc is documented"
  #f) ;; doc must not be the last element
(display (procedure-documentation documented-proc))
(newline)
;; variables have no docstrings but
;; properties can be set manually.
(define variable #f)
(set-object-property! variable 'documentation
  "Variable is documented")
(display (object-property variable 'documentation))
```

---

Proc is documented

Variable is documented

You can get the documentation with `help` or `,d` on the REPL:

```
,d documented-proc => Proc is documented
```

```
,d variable => Variable is documented
```

For generating documentation from comments, there's `guild doc-snarf`.

---

```
;; Proc docs can be snarfed
(define (snarfed-proc arg)
  #f)
;; Variable docs can be snarfed
(define snarfed-variable #f)
```

---

If this is saved as `hello.scm`, get the docs via

---

```
guild doc-snarf --texinfo hello.scm
```

---

## 41 Read the docs

Now you understand the heart of code. With this as the core there is one more step, the lifeblood of programming: learning more. Sources:

- [Guile Reference manual](#)
- [Guile Library](#)
- [Scheme Requests for Implementation \(SRFI\)](#): tagged libraries
- [Scheme standards \(RnRS\)](#), specifically [r7rs-small](#) ([pdf](#))
- List of [tools and libraries](#)
- [Rosetta Code](#) with solutions to many algorithm problems

**Info manuals** can often be read online, but the `info` commandline application and `info` in Emacs (`C-h i`) are far more efficient and provide full-text search. You can use them to read the Guile reference manual and some libraries. Get one by installing [texinfo](#) or [Emacs](#).

In **interactive guile** (the REPL), you can check documentation:

---

```
(help string-append)
```

---

```
`string-append' is a procedure in the (srfi srfi-13) module.
```

```
- Scheme Procedure: string-append . args
```

```
  Return a newly allocated string whose characters form the
  concatenation of the given strings, ARGS.
```

---

```
,help
```

---

```
Help Commands [abbrev]:
```

```
...
```

*Note: the full links are printed in the list of links on page 68.*

## 42 Create a manual as package documentation with texinfo

Create a doc/ folder and add a hello.texi file.

An **example file** can look like the following:

---

```
@documentencoding UTF-8
@settitle Hello World
@c This is a comment; The Top node is the first page
@node Top

@c Show the title and clickable Chapter-names as menu
@top
@menu
* First Steps::
* API Reference::
@end menu

@contents
@node First Steps
@chapter First Steps
@itemize
@item
Download from ...
@item
Install: @code{make}.
@end itemize

Example:
@lisp
(+ 1 2)
@result{} 3
@end lisp
```

```
@node API Reference
@chapter API Reference
@section Procedures
@subsection hello
Print Hello
@example
hello
@end example
```

---

Add a Makefile in the doc/ folder:

---

```
all: hello.info hello.epub hello_html/index.html
hello.info: hello.texi
    makeinfo hello.texi
hello.epub: hello.texi
    makeinfo --epub hello.texi
hello_html/index.html: hello.texi
    makeinfo --html hello.texi
```

---

Run make in the doc/ folder:

---

```
make
```

---

Read the docs with **calibre** or the **browser** or plain **info**:

---

```
calibre hello.epub & \
firefox hello_html/index.html & \
info -f ./hello.info
```

---

*The HTML output is plain. You can adapt it with CSS by adding `--css-include=FILENAME` or `--css-ref=URL`.*

*Alternately you can write an [Org Mode](#) document and evaluate (`require 'ox-texinfo`) to activate exporting to texinfo.*

## 43 Track changes with a version tracking system like Mercurial or Git

For convenience, first initialize a version tracking repository, for example [Mercurial](#) or [Git](#).

---

```
# either Mercurial
hg init hello
# or Git
git init hello
# enter the repository folder
cd hello-scm/
```

---

Now you can add new files with

---

```
# in Mercurial
hg add FILE
# in Git
git add FILE
```

---

And take a snapshot of changes with

---

```
# in Mercurial
hg commit -m "a change description"
# in Git
git commit -a -m "a change description"
```

---

It is good practice to always use a version tracking system.

For additional information and how to compare versions, go back in time, or publish your code if you want to, see the [Mercurial Guide](#) or the [Git Tutorial](#).

## 44 Package with autoconf and automake

Create a `configure.ac` file with name, contact info and version.

---

```
dnl configure.ac
dnl Name, Version, and contact information.
AC_INIT([hello], [0.0.1], [myName@example.com])
# Set a supported Guile version as @GUILE@, then init
↪ building
GUILE_PKG([3.0])
GUILE_PROGS
GUILE_SITE_DIR
AC_PREFIX_PROGRAM([guile])
AM_INIT_AUTOMAKE([gnu])
AC_CONFIG_FILES([Makefile])
AC_OUTPUT
```

---

Add a `Makefile.am` with build rules. Only the start needs to be edited:

---

```
bin_SCRIPTS = hello # program name
SUFFIXES = .scm .sh
SCHEME = hello.scm # source files
hello: $(SCHEME)
    echo "#!/usr/bin/env bash" > "$@" && \
    echo 'exec -a "$$0" guile' \
        '-L "$$(dirname "$$(realpath "$$0)")"' \
        '-L "$$(dirname "$$(realpath'
        ↪ "$$0)")"/../share/guile/site/3.0/"' \
        '-s "$$0" "$$@"' \
        >> "$@" && echo ";; exec done: !#" >> "$@" && \
    cat "$<" >> "$@" && chmod +x "$@"
TEXINFO_TEX = doc/hello.texi # else it needs texinfo.texi
info_TEXINFOS = doc/hello.texi
# add library files, prefix nobase_ preserves directories
```



nobase\_site\_DATA =

---

The rest of the Makefile.am can be copied verbatim:

---

```
## Makefile.am technical details

# where to install guile modules to import. See
# https://www.gnu.org/software/automake/manual/html_node/Alte
# ↪ rnative.html
sitedir = $(datarootdir)/guile/site/$(GUILE_EFFECTIVE_VERSION)

GOBJECTS = $(nobase_site_DATA:%.w=%.go)
nobase_go_DATA = $(GOBJECTS)
godir=$(libdir)/guile/$(GUILE_EFFECTIVE_VERSION)/site-ccachep

# Make sure that the mtime of installed compiled files
# is greater than that of installed source files. See:
# http://lists.gnu.org/archive/html/guile-devel/2010-07/msg00
# ↪ 125.html
# The missing underscore before DATA is intentional.
guile_install_go_files = install-nobase_goDATA
$(guile_install_go_files): install-nobase_siteDATA

EXTRA_DIST = $(SCHEME) $(info_TEXINFOS) $(nobase_site_DATA)
CLEANFILES = $(GOBJECTS) $(wildcard *~)
DISTCLEANFILES = $(bin_SCRIPTS) $(nobase_site_DATA)

# precompile all source files
.scm.go:
    $(GUILE_TOOLS) compile $(GUILE_WARNINGS) \
        -o "$@" "$<"
```

---

---

```
## Makefile.am help
```

```
.PHONY: help
```

```
help: ## Show this help message.
```

```
    @echo 'Usage:'
```

```
    @echo ':make [target] ...' \
        | sed "s/\(target\)\/\\x1b[36m\1\\x1b[m/" \
        | column -c2 -t -s :
```

```
    @echo
```

```
    @echo 'Custom targets:'
```

```
    @echo -e "$$(grep -hE '^\S+:.*##' $(MAKEFILE_LIST) \
        | sed -e \
        's/:.*##\s*/:/' -e \
        's/^\(.\+\):\(.*\)\/:\\x1b[36m\1\\x1b[m:\2/' \
        | column -c2 -t -s :)"
```

```
    @echo
```

```
    @echo '(see ./configure --help for setup options)'
```

---

*This assumes that the folder `hello` uses a *Version tracking system*.*

---

```
## Makefile.am basic additional files
.SECONDARY: ChangeLog AUTHORS
ChangeLog: ## create the ChangeLog from the history
    echo "For user-visible changes, see the NEWS file" > "$@"
    echo >> "$@"
    if test -d ".git"; \
    then cd "$(dirname "$(realpath .git)")" \
    && git log --date-order --date=short \
    | sed -e '/^commit.*$/d' \
    | awk '/^Author/ {sub(/\$/,""); getline t; print $0 \
    ↪ t; next}; 1' \
    | sed -e 's/^Author: //g' \
    | sed -e \
    's/\(.*\)>Date:  \([0-9]*-[0-9]*-[0-9]*\)/\2 \
    ↪ \1>/g' \
    | sed -e 's/~\(.*\) \(\)\t\(.*\)/\3 \1 \2/g' \
    >> "$@"; cd -; fi
    if test -d ".hg"; \
    then hg -R "$(dirname "$(realpath .hg)")" \
    log --style changelog \
    >> "$@"; fi
AUTHORS: ## create the AUTHORS file from the history
    if test -d ".git"; \
    then cd "$(dirname "$(realpath .git)")" \
    && git log --format='%aN' \
    | sort -u >> "$@"; cd -; fi
    if test -d ".hg"; \
    then hg -R "$(dirname "$(realpath .hg)")" \
    --config extensions.churn= \
    churn -t "{author}" >> "$@"; fi
```

---

Now create a README and a NEWS file:

---

```
#+title: Hello

A simple example project.

* Requirements

- Guile version 3.0.10 or later.

* Build the project

#+begin_src bash
, # Build the project
autoreconf -i && ./configure && make
, # Create a distribution tarball
autoreconf -i && ./configure && make dist
#+end_src

* License

GPLv3 or later.
```

---

```
hello 0.0.1

- initialized the project
```

---

And for the sake of this example, a simple hello.scm file:

---

```
(display "Hello World!\n")
```

---

## 44.1 Init a project with hall

To simplify the setup, start it by getting the tool [guile-hall](#) (named Hall) as described in the manual under [Distributing Guile Code](#). Then create a new project:

---

```
hall init hello -a "My Name" \  
                -e "myName@example.com" \  
                --execute  
cd hello && hall build --execute
```

---

*Add `-license` to change the license; GPLv3 or later is the default.*

Hall creates a `configure.ac` file with name, contact information and version, and a `Makefile.am` with build rules. It also automatically adds TEXINFO-rules for the folder `doc/`.

## 45 Deploy a project to users

Enable people to access your project as a webserver behind nginx, as clientside browser-app, or as Linux package (Guix tarball).

**Browser: as webserver.** *On the web no one knows you're a Scheme.*

Guile provides a `webserver` module. A minimal webserver:

---

```
(import (web server)
        (web request)
        (web response)
        (web uri))
(define (handler request body)
  (define path (uri-path (request-uri request)))
  (values (build-response
            #:headers `((content-type . (text/plain)))
            #:code 404)
          (string-append "404 not found: " path)))
(define v4 #t)
;; choose either IPv4 or IPv6; to suport both, run twice.
;; (run-server handler 'http
;;   (if v4 '(:port 8081)
;;       '(:family AF_INET6 #:port 8081)))
```

---

An `nginx` SSL Terminator (`/etc/nginx/sites-enabled/default`):

---

```
server {
  server_name domain.example.com;
  location / {
    proxy_pass http://localhost:8081;
  }
}
```

---

Set up SSL support with `certbot` (this edits the config file).

**Browser again: clientside wasm.** To run clientside, you can package your project with [Hoot](#): build an interface and compile to wasm:

---

```
(use-modules (hoot ffi)) ;; guile-specific import
(define-foreign document-body "document" "body"
  -> (ref null extern))
(define-foreign make-text-node "document" "createTextNode"
  (ref string) -> (ref null extern))
(define-foreign append-child! "element" "appendChild"
  (ref null extern) (ref null extern)
  -> (ref null extern))

(append-child! (document-body) ;; Your logic
  (make-text-node "Hello, world!"))
```

---

Transpile with `guild compile-wasm`. If you run Guix:

---

```
guix shell guile-hoot guile-next -- \
  guild compile-wasm -o hoot.wasm hoot.scm
```

---

Get reflection tools from Guile Hoot (licensed Apache 2.0) with Guix:

---

```
guix shell guile-hoot guile-next -- bash -c \
  'cp $GUIX_ENVIRONMENT/share/guile-hoot/*/reflect*/{*.js,}
  ↪ *.wasm} ./'
```

---



---

```
window.addEventListener("load", () =>
  Scheme.load_main("./hoot.wasm", {
    user_imports: { document: {
      body() { return document.body; },
      createTextNode: Document.prototype
        .createTextNode.bind(document)
    }, element: {
      appendChild(parent, child) {
        return parent.appendChild(child);}}}}));
```

---

Include `reflect.js` and `hoot.js` from a HTML page:

---

```
<html><head><title>Hello Hoot</title>
<script type="text/javascript" src="reflect.js"></script>
<script type="text/javascript" src="hoot.js"></script>
</head><body><h1>Hoot Test</h1></body></html>
```

---

For local testing, hoot provides a minimal webserver:

---

```
guix shell guile-hoot guile-next -- \
  guile -c '(@ (hoot web-server) serve)'
```

---

## Linux: Guix tarball. *The package is the tarball.* — Ludovic

Guix can assemble a tarball of all dependencies. If you already have an autoconf project, this just requires a `guix.scm` file:

---

```
(import (gnu packages web)
        (gnu packages bash)
        (gnu packages guile)
        (gnu packages guile-xyz)
        (gnu packages pkg-config)
        (guix packages)
        (guix gexp)
        (guix build-system gnu)
        (prefix (guix licenses) license:))

(define-public guile-doctests
  (package
    (name "guile-doctests")
    (version "0.0.1")
    (source (local-file "." "" #:recursive? #t))
    (build-system gnu-build-system)
    (propagated-inputs `(("guile" ,guile-3.0)
                         ("pkg-config" ,pkg-config)
                         ("bash" ,bash)))
    (home-page "https://hg.sr.ht/~arnebab/guile-doctests")
    (synopsis "Tests in procedure definitions")
    (description "Guile module to keep tests directly in
  ↪ your procedure definition.")
    (license license:lgpl3+)))
```

### guile-doctests

---

First test building `guix build -f guix.scm`, then test running with `guix shell -f guix.scm` and once both work, create your package with:

---

```
guix pack -e '(load "guix.scm")' \
  -RR -S /bin=bin -S /share=share
```

---

Copy the generated tarball. It can be executed with:

---

```
mkdir hello && cd hello && tar xf TARBALL_FILE && \
  bin/doctest
```

---

Since this tarball generation is a bit finicky, there is a [guile-doctests](#) package with a working example setup.

Once you have `guix pack` working, you can also create `dockerfiles` and other packages to deploy into different publishing infrastructure.

*To be continued: Scheme is in constant development and deploying Guile programs is getting easier. Lilypond solved Windows.*

*Also see the [Map of R<sup>7</sup>RS](#) and the [Scheme primer](#) to keep learning.*

**You are ready.**

**Go and build a project you care about.**

# List of Links

draketo.de: <a href="https://www.draketo.de">https://www.draketo.de</a> . . . . .	1
Guile: <a href="https://www.gnu.org/software/guile">https://www.gnu.org/software/guile</a> . . . . .	1
Attribution - Sharealike: <a href="https://creativecommons.org/licenses/by-sa/4.0/">https://creativecommons.org/licenses/by-sa/4.0/</a> . . . . .	7
Real and Rational Numbers: <a href="https://www.gnu.org/software/guile/manual/html_node/Reals-and-Rationals.html">https://www.gnu.org/software/guile/manual/html_node/Reals-and-Rationals.html</a> . . . . .	21
r5rs numbers: <a href="https://groups.csail.mit.edu/mac/ftplib/scheme-reports/r5rs-html/r5rs_8.html#SEC50">https://groups.csail.mit.edu/mac/ftplib/scheme-reports/r5rs-html/r5rs_8.html#SEC50</a> . . . . .	21
IEEE 754: <a href="https://ieeexplore.ieee.org/document/8766229">https://ieeexplore.ieee.org/document/8766229</a> . . . . .	21
recursion wins: <a href="http://www.draketo.de/light/english/recursion-wins">http://www.draketo.de/light/english/recursion-wins</a> . . . . .	31
ice-nine: <a href="https://en.wikipedia.org/w/index.php?title=Ice-nine&amp;oldid=1204900352">https://en.wikipedia.org/w/index.php?title=Ice-nine&amp;oldid=1204900352</a> . . . . .	32
in the Guile Reference manual: <a href="https://www.gnu.org/software/guile/manual/html_node/SRFI-Support.html">https://www.gnu.org/software/guile/manual/html_node/SRFI-Support.html</a> . . . . .	32
srfi.schemers.org: <a href="https://srfi.schemers.org/">https://srfi.schemers.org/</a> . . . . .	32
Revised Report on Scheme: <a href="https://standards.scheme.org/">https://standards.scheme.org/</a> . . . . .	36
Vectors: <a href="https://standards.scheme.org/corrected-r7rs/r7rs-Z-H-8.html#TAG:_tex2page_sec_6.8">https://standards.scheme.org/corrected-r7rs/r7rs-Z-H-8.html#TAG:_tex2page_sec_6.8</a> . . . . .	36
forestry commission technical paper 1993: <a href="https://cdn.forestresearch.gov.uk/1993/09/fctp004.pdf">https://cdn.forestresearch.gov.uk/1993/09/fctp004.pdf</a> . . . . .	37
Waldwissen: <a href="https://www.waldwissen.net/de/lebensraum-wald/baeume-und-waldpflanzen/laubbaeume/birke-eine-baumart-mit-potenzial">https://www.waldwissen.net/de/lebensraum-wald/baeume-und-waldpflanzen/laubbaeume/birke-eine-baumart-mit-potenzial</a> . . . . .	37
BaumUndErde: <a href="https://www.baumunderde.de/stammgewicht-rechner/">https://www.baumunderde.de/stammgewicht-rechner/</a> . . . . .	37
srfi 64: <a href="https://srfi.schemers.org/srfi-64/srfi-64.html">https://srfi.schemers.org/srfi-64/srfi-64.html</a> . . . . .	41
literal: <a href="https://standards.scheme.org/corrected-r7rs/r7rs-Z-H-6.html">https://standards.scheme.org/corrected-r7rs/r7rs-Z-H-6.html</a> . . . . .	45
From the standard: <a href="https://standards.scheme.org/corrected-r7rs/r7rs-Z-H-6.html#TAG:_tex2page_sec_4.2.8">https://standards.scheme.org/corrected-r7rs/r7rs-Z-H-6.html#TAG:_tex2page_sec_4.2.8</a> . . . . .	48
Guile Reference manual: <a href="https://www.gnu.org/s/guile/manual/guile.html">https://www.gnu.org/s/guile/manual/guile.html</a> . . . . .	52
Guile Library: <a href="https://www.nongnu.org/guile-lib/doc/">https://www.nongnu.org/guile-lib/doc/</a> . . . . .	52
Scheme Requests for Implementation (SRFI): <a href="https://srfi.schemers.org/">https://srfi.schemers.org/</a> . . . . .	52
Scheme standards (RnRS): <a href="https://standards.scheme.org/">https://standards.scheme.org/</a> . . . . .	52
r7rs-small: <a href="https://standards.scheme.org/corrected-r7rs/r7rs.html">https://standards.scheme.org/corrected-r7rs/r7rs.html</a> . . . . .	52
pdf: <a href="https://standards.scheme.org/unofficial/errata-corrected-r7rs.pdf">https://standards.scheme.org/unofficial/errata-corrected-r7rs.pdf</a> . . . . .	52
tools and libraries: <a href="https://www.gnu.org/software/guile/libraries/">https://www.gnu.org/software/guile/libraries/</a> . . . . .	52
Rosetta Code: <a href="https://rosettacode.org/wiki/Category:Scheme">https://rosettacode.org/wiki/Category:Scheme</a> . . . . .	52
texinfo: <a href="https://www.gnu.org/software/texinfo/">https://www.gnu.org/software/texinfo/</a> . . . . .	52
Emacs: <a href="https://gnu.org/software/emacs">https://gnu.org/software/emacs</a> . . . . .	52
Org Mode: <a href="https://orgmode.org">https://orgmode.org</a> . . . . .	54
Mercurial: <a href="https://mercurial-scm.org">https://mercurial-scm.org</a> . . . . .	55
Git: <a href="https://git-scm.org">https://git-scm.org</a> . . . . .	55
Mercurial Guide: <a href="https://mercurial-scm.org/guide">https://mercurial-scm.org/guide</a> . . . . .	55
Git Tutorial: <a href="https://git-scm.com/docs/gittutorial">https://git-scm.com/docs/gittutorial</a> . . . . .	55
guile-hall: <a href="https://gitlab.com/a-sassmannshausen/guile-hall">https://gitlab.com/a-sassmannshausen/guile-hall</a> . . . . .	62
Distributing Guile Code: <a href="https://www.gnu.org/software/guile/manual/html_node/Distributing-Guile-Code.html">https://www.gnu.org/software/guile/manual/html_node/Distributing-Guile-Code.html</a> . . . . .	62
webserver: <a href="https://www.gnu.org/s/guile/manual/guile.html#Web-Server">https://www.gnu.org/s/guile/manual/guile.html#Web-Server</a> . . . . .	63
nginx: <a href="https://nginx.org/">https://nginx.org/</a> . . . . .	63
certbot: <a href="https://certbot.eff.org/instructions?ws=nginx&amp;os=pip">https://certbot.eff.org/instructions?ws=nginx&amp;os=pip</a> . . . . .	63
Hoot: <a href="https://spritely.institute/hoot/">https://spritely.institute/hoot/</a> . . . . .	64
guile-doctests: <a href="https://hg.sr.ht/~arnebab/guile-doctests">https://hg.sr.ht/~arnebab/guile-doctests</a> . . . . .	67
Map of R7RS: <a href="https://misc.lassi.io/2022/map-of-r7rs-small.html">https://misc.lassi.io/2022/map-of-r7rs-small.html</a> . . . . .	67
Scheme primer: <a href="https://spritely.institute/static/papers/scheme-primer.html">https://spritely.institute/static/papers/scheme-primer.html</a> . . . . .	67





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