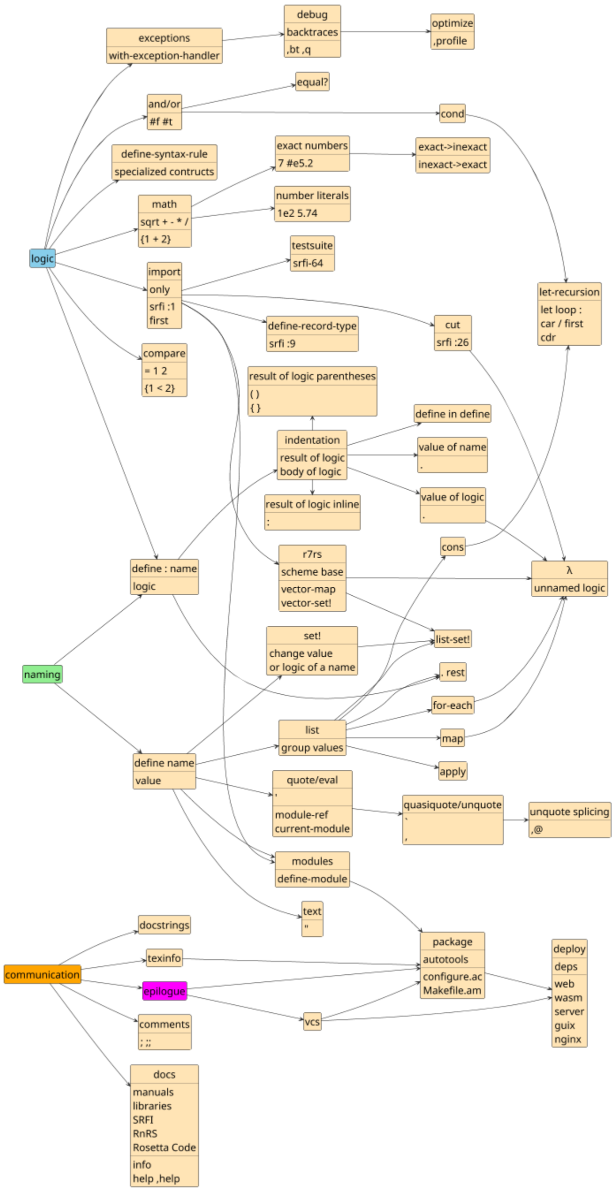
Dr. Arne Babenhauserheide / draketo.de

Naming and Logic

programming essentials with Wisp

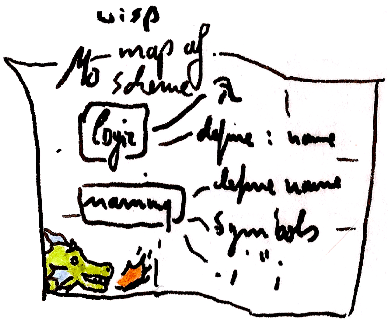
and a three-fold Zen for Scheme



Find the heart of programming with the map of Scheme.

To follow along, install Wisp and try the examples as you read.

Best practices in Lisp with fewer parentheses.



Contents

i Preface

Why this book? To provide 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 Wisp? Wisp is the simplest possible indentation based syntax which is able to express all possibilities of Lisp. It is included in Guile Scheme, the official extension language of the GNU project.

»best I've seen; pythonesque, hides parens but keeps power«
— Christine Lemmer-Webber, 2015

How to get Wisp? Download and install Wisp from the website `www.draketo.de/software/wisp` — then open the REPL by executing `wisp` in the terminal. The REPL is where you type and try code interactively. Or install `Guile 3.0.10+` and run `guile --language=wisp` or `guile3.0 --language=wisp`. This text assumes GNU Linux.

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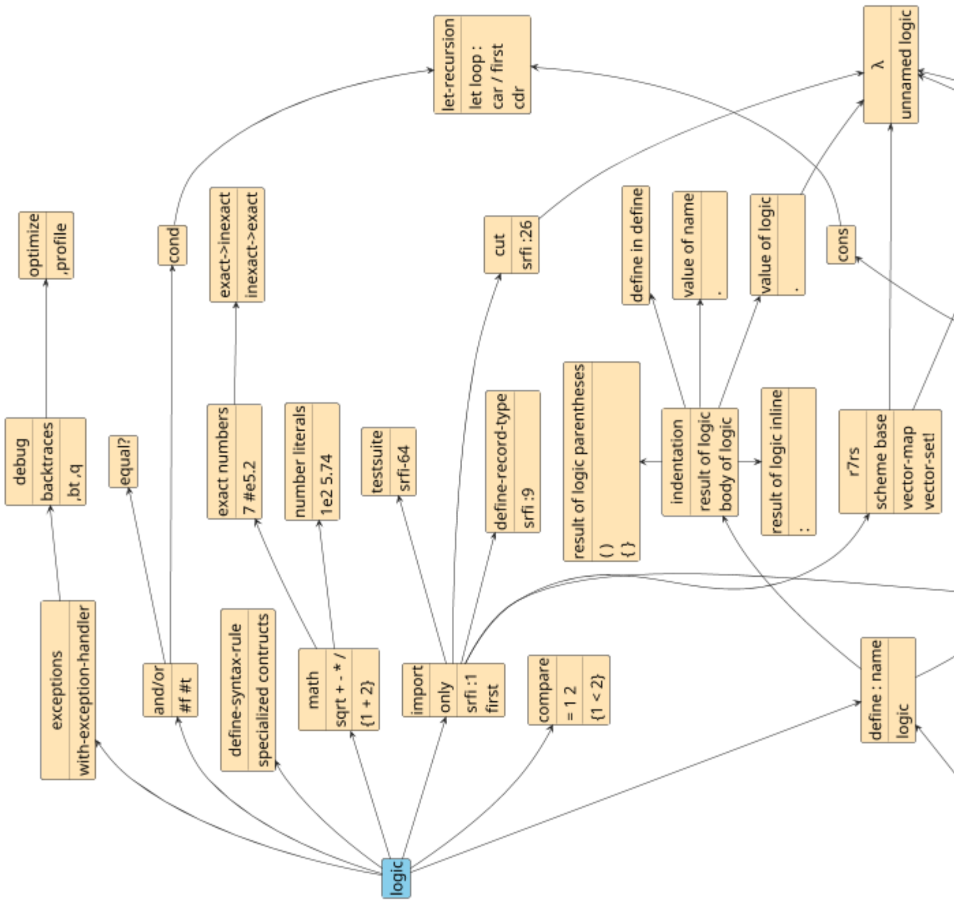
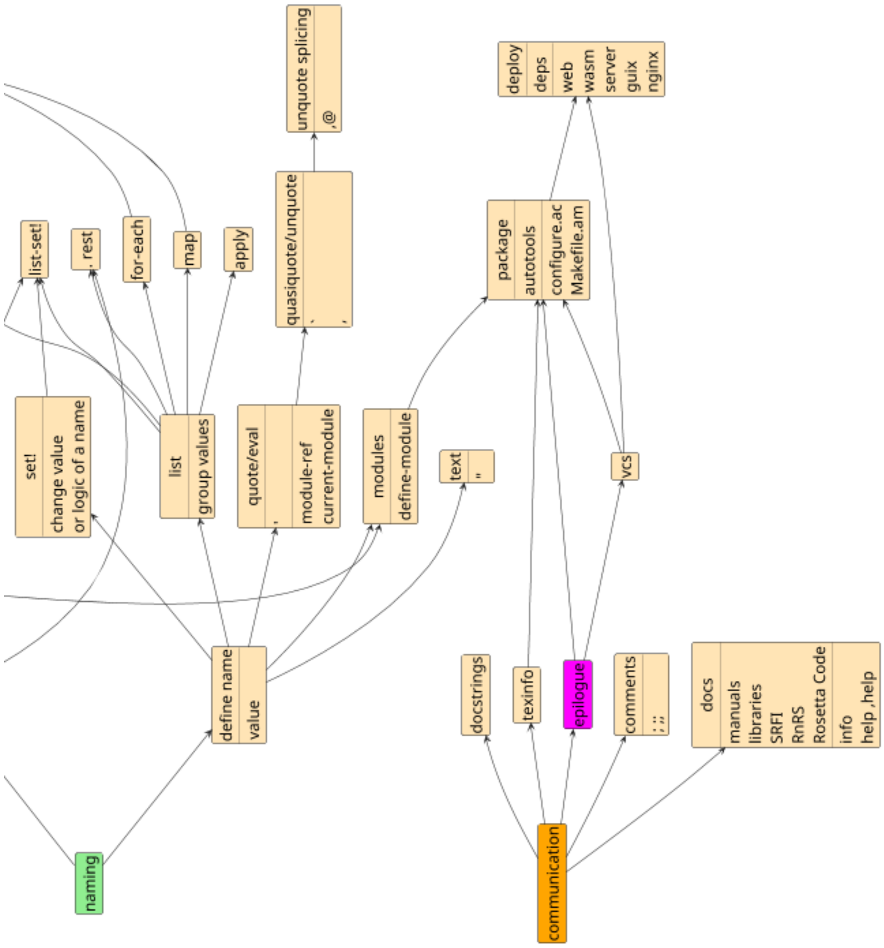
ii The Map of Scheme

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define name
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1 Name a value with define

Use `define` to name a value. Use `.` to return a value.

```
define small-tree-height-meters 3
define large-tree-height-meters 5
. small-tree-height-meters
```

After typing code in the REPL, **hit enter three times**. It returns:

```
$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
```

2 Add comments with ;

```
define birch-height/m 3
;; this is a comment
define height ;; comment at the end
  ;; comment between lines
  . 5 ; return the value to define
```

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

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

3 Compare numbers

```
= 3 5
```

```
$1 = #f
```

```
= 3 3
```

```
$1 = #t
```

`#t` means true, `#f` means false.

Returns the *result* of logic without needing a period (`.`).

The logic comes first. This is clear for `=`, but easy to misread for `<`.

```
< 3 5 ;; is 3 smaller than 5? #true
< 5 3 ;; is 5 smaller than 3? #false
> 3 5 ;; is 3 bigger than 5? #false
> 5 3 ;; is 5 bigger than 3? #true

> 3 3 ;; is 3 bigger than 3? #false
>= 3 3 ;; is 3 bigger than or equal to 3? #true
<= 3 3 ;; is 3 smaller than or equal to 3? #true
```

```
$1 = #t
$2 = #f
$3 = #f
$4 = #t
$5 = #f
$6 = #t
$7 = #t
```

4 Use infix in logic

```
. {3 = 5}
. {3 < 5}
. {3 > 5}
```

```
$1 = #f
$2 = #t
$3 = #f
```

Infix logic gives a value, so you need `.` to return it.

You can only use curly braces for infix operations.

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

```
. {{5 < 3} equal? #f}
```

```
$1 = #t
```

Or to name it as value:

```
define is-math-sane? {3 < 5}
. is-math-sane?
```

```
$1 = #t
```

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

5 Use logic with true and false

```
and #t #t
and #f #t
or #f #t
or #f #f
```

```
$1 = #t
$2 = #f
$3 = #t
$4 = #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.

```
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
```

```
$1 = #t
$2 = #f
$3 = #f
$4 = #t
$5 = #t
$6 = #f
```

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.

6 Use named values in logic

```
define small-tree-height/m 3
define large-tree-height/m 5
. {small-tree-height/m < large-tree-height/m}
```

```
$1 = #t
```

7 Name the result of logic with indentation

```
define birch-h/m 3
define chestnut-h/m 5
define same-height?
  = birch-h/m chestnut-h/m
define smaller?
  . {birch-h/m < chestnut-h/m} ;; infix
. smaller?
```

```
$1 = #t
```

The more indented line *returns* its value to the previous, less indented line.

The infix gives a value, so it needs the `.` as prefix to return the value.

8 Name logic with `define :`

```
define : same-height? tree-height-a tree-height-b
  = tree-height-a tree-height-b
same-height? 3 3
;; also works with infix
. {3 same-height? 3}
```

```
$1 = #t
$2 = #t
```

By convention, logic that returns true or false has the suffix `?`. You can use your own named logic like all other logic. Even with infix.

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

The first word is the name of the logic. The others are the arguments the logic operates on. The indented lines with the logic named here are called the **body**. The body of named logic can have multiple lines. Only the value of the last is returned.

```
define : unused-comp value
  = 2 value ;; not returned
  = 3 value ;; returned
unused-comp 2
unused-comp 3
```

```
$1 = #f
$2 = #t
```

9 Name a name using `define` with .

```
define small-tree-height-meters 3
define height
  . small-tree-height-meters
. height
```

```
$1 = 3
```

After you name a name, the new name holds the same value as the original name.

. returns the value of its line.

10 Return the value of logic with .

```
define : larger-than-4? size
  . {size > 4}
. larger-than-4?
```

```
$1 = #<procedure larger-than-4? (size)>
```

The value of logic defined with `define :` is a `procedure` — often called `proc` for brevity. 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.

11 Name inside `define :` with `define`

```
define birch-h/m 3
define : birch-is-small
  define reference-h/m 4
  . { birch-h/m < reference-h/m }
birch-is-small
```

```
$1 = #t
```

Only the last part of the body of `define :` is returned.

Note the `.` in front of the `{ birch-h/m < reference-h/m }`: a calculation inside braces is executed in-place. It is its result, so its value needs to be 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 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 Name the result of logic in one line with : or ()

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

define same-height? : = birch-h/m chestnut-h/m
. same-height?
define same-height-again? (= birch-h/m chestnut-h/m)
. same-height-again?
```

```
$1 = #f
$2 = #f
```

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

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

define same-height? {birch-h/m = chestnut-h/m}
. same-height?
;; define logic
define : same? tree-height-a tree-height-b
  = tree-height-a tree-height-b
;; using the defined logic looks like defining it
define same2? : same? birch-h/m chestnut-h/m
. same2?
```

```
$1 = #f
$2 = #f
```

13 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. Line breaks 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 \\.

Text is stronger than comments:

```
define with-comment ;; belongs to coment
  ;; comment
  . "Hello ;; part of the text"
. with-comment
```

```
$1 = "Hello ;; part of the text"
```

Return the value with `.` to name text on its own line.

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

14 Take decisions with `cond`

```
define chestnut-h/m 5
define tree-description
  cond
    {chestnut-h/m > 4} ;; condition
      . "large tree"   ;; result
    : = 4 chestnut-h/m ;; check returned value
      . "four meter tree"
    else
      . "small tree"
. tree-description
```

```
$1 = "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`).

```
cond
  5
    . #t
  else ;; else is #true in cond
    . #f
cond
  #f #f   ;; can put the value directly
  else #t ;; on the same line, if not using :
```

```
$1 = #t
$2 = #t
```

To use named logic, prefix it with `:` or enclose it in parentheses `()` for prefix or braces `{}` for infix to check its *value*. `:` needs a line-break after the condition.

15 Use fine-grained numbers with number-literals

```
define more-precise-height 5.32517
define 100-meters 1e2 ;; 1 times 10 to the power of 2
. more-precise-height
. 100-meters
```

```
$1 = 5.32517
$2 = 100.0
```

These are floating point numbers. They store approximate values in 64 bit binary, depending on the platform. Read the details in the Guile Reference manual section Real and Rational Numbers, the r5rs numbers, and IEEE 754.[1]

16 Use exact numbers with #e and quotients

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

```
$1 = 1/5
$2 = 1/5
```

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

[1] All links are listed on page 64.

17 Turn exact numbers into decimals with `exact->inexact`

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

```
$1 = 0.2
$2 = 0.2
$3 = -2.0e7
```

The inverse is `inexact->exact`:

```
inexact->exact 0.5
```

```
$1 = 1/2
```

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

```
inexact->exact 0.2
. #e0.2
```

```
$1 = 3602879701896397/18014398509481984
$2 = 1/5
```

18 Use math with the usual operators as logic

```
define one-hundred
  * 10 10 ;; multiply with *
define half-hundred : / one-hundred 2 ;; divide with /
. half-hundred
```

```
$1 = 50
```

Remember that names cannot be valid numbers!

```
define 100 ;; error!
  + 90 10
```

```
While compiling expression:
Syntax error:
unknown location: source expression failed to match any
↪  pattern in form (define 100 (+ 90 10))
```

Using infix via curly braces {} is useful for math:

```
define one-hundred {10 * 10}
define half-hundred {one-hundred / 2}
. half-hundred ;; tallest northern red oak
```

```
$1 = 50
```

19 Return a list of values with `list`

```
list 3 5
define known-heights
  list 3 3.75 5 100
. known-heights
```

```
$1 = (3 5)
$2 = (3 3.75 5 100)
```

You can put values on their own lines by returning their value: `.` returns all the values in its line. Different from `define :`, list keeps all values, not just the last.

```
define known-heights-2
  list 3
     . 3.75 5
     . 100
define known-heights-3
  list
    . 3
    . 3.75
    . 5
    . 100
define : last-height
  . 3 3.75 5 100 ;; only the last (100) is returned
= 100 : last-height
. known-heights-3
```

```
$1 = #t
$2 = (3 3.75 5 100)
```

20 Import pre-defined named logic and values with `import`

```
import : ice-9 pretty-print
         srfi :1 lists ;; no space after the :

pretty-print ;; format a structure nicely
  list 12 : list 34
    . 5 6
first : list 1 2 3 ;; 1
second : list 1 2 3 ;; 2
third : list 1 2 3 ;; 3
member 2 : list 1 2 3 ;; includes 2 => 2 3 => #true
```

```
(12 (34) 5 6)
$1 = 1
$2 = 2
$3 = 3
$4 = (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 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 SRFI chapter of the Guile Reference Manual. More can be found on 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 ;; no second

first : list 1 2 3 ;; 1
second : list 1 2 3 ;; error
```

```
$1 = 1
ice-9/boot-9.scm:1705:22: In procedure raise-exception:
Unbound variable: second

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

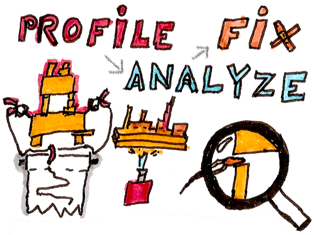
21 Optimize for performance with `,profile`

When in the interactive REPL, you can get a runtime profile. Fast operations may need to be run in a loop to get a robust sample:

```
define runs : iota 1000000 ;; numbers from 0 to 999999
,profile for-each number->string runs
```

```
%      cumulative   self
time    seconds     seconds  procedure
 50.00       0.13      0.07  ice-9/boot-9.scm:260:2:for-each
 50.00       0.07      0.07  number->string
---
Sample count: 4
Total time: 0.132540664 seconds (0.111396361 seconds in GC)
```

To look deeper, use `,disassemble`.
In code files `import : statprof`.



22 Get the result of logic inline with parentheses (), braces {}, or colon :

```
list 1 2 (+ 1 2) 4
list 1 2 {1 + 2} 4
list 1 2 : + 1 2
   . 4 ;; use . to continue the arguments after :
```

```
$1 = (1 2 3 4)
$2 = (1 2 3 4)
$3 = (1 2 3 4)
```

Line breaks and indentation are ignored inside parentheses, except for the value of `text` (`strings`).

The operators that need linebreaks are disabled inside parentheses: colon `:` and period `.` neither get the value nor return it, but the last value is returned implicitly. This is the default in regular Scheme.

`:` needs linebreaks, because it only goes to the end of the line.

`.` needs linebreaks, because it only applies at the beginning of the line (after indentation).

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.

23 Compare structural values with equal?

```
define known-heights
  list 3 3.75 5 100
define known-heights-2
  list 3 3.75 5
     . 100
define known-heights-3
  list
    . 3 3.75
    . 5 100
= 3 3 3
equal? known-heights known-heights-2 known-heights-3
```

```
$1 = #t
$2 = #t
```

`equal?` compares whether all values it receives are equal. For structural values like lists, being equal means that all contained elements have equal value and are in the same order.

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

24 Apply logic to a list of values with `apply`

```
apply = : list 3 3
equal?
  = 3 3
  apply =
    list 3 3
```

```
$1 = #t
$2 = #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 ;; the same as = 1 1 1 1
```

```
$1 = #t
```

Using `apply proc a (list b c)` has the same result as calling proc with the arguments `a b c`:

```
define : proc x y z
    < x y z
apply proc 1 : list 2 3
proc 1 2 3
```

```
$1 = #t
$2 = #t
```

25 Get the arguments of named logic as list with `. rest`

```
define : same? heights
  apply = heights
same? : list 1 1 1 ;; needs a list to use apply
same?
  list 1 1 1
define : same2? . heights
  apply = heights
same2? 1 1 1 ;; takes values directly
same2?
  . 1 1 1
```

```
$1 = #t
$2 = #t
$3 = #t
$4 = #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
same? 1 1 1 1 ;; 4 arguments, the last 2 are rest
```

```
(1 1 (1 1))
$1 = #t
```

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

26 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
set! birch-h/m =
. birch-h/m
```

```
$1 = 3.74
$2 = #<procedure = (#:optional _ _ . _)>
```

It is common to suffix logic with `!` if it changes values of names.

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

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

```
define birch-h/m 3
define includes-birch-height #f
define : set-true-if-birch-height! height/m
  cond
    {birch-h/m = height/m}
      set! includes-birch-height #t
define heights : list 3 3.75 5 100
for-each set-true-if-birch-height! heights
. includes-birch-height
```

```
$1 = #t
```

28 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
. heights
map same-height-as-birch?
  . heights
map +
  list 1 2 3
  list 3 2 1
map list
  list 1 2 3
  list 3 2 1
```

```
$1 = (3 3.75 5 100)
$2 = (#t #f #f #f)
$3 = (4 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 colums and rows:

```
apply map list
  list : list 1 2 3
         list 3 2 1
```

```
$1 = ((1 3) (2 2) (3 1))
```

29 Create nameless logic with `lambda`

```
define : is-same-height? a b
  > a b ;; <- this is a mistake
. is-same-height?
is-same-height? 3 3
define : fixed a b
  = a b
set! is-same-height? fixed
. is-same-height? ;; but now called "fixed" in output!
is-same-height? 3 3
;; 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 again
. is-same-height?
is-same-height? 3 3
```

```
$1 = #<procedure is-same-height? (a b)>
$2 = #f
$3 = #<procedure fixed (a b)>
$4 = #t
$5 = #<procedure is-same-height? (a b)>
$6 = #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.

30 Reuse your logic with `let-recursion`

Remember the `for-each` example:

```
define includes-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! includes-birch-height #t
for-each set-true-if-birch-height! heights
. includes-birch-height
```

```
$1 = #t
```

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

```
define heights : list 3 3.75 5 100
define : includes-birch-height? heights
  define birch-h/m 3
  let loop : : heights heights
    cond
      (null? heights) #f ;; done: not found
      : = birch-h/m : car heights ;; car is first
        . #t ;; done: one found
      else
        loop : cdr heights ;; drop the first, try again
includes-birch-height? heights
```

```
$1 = #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`, `+`, `-`, `1+`, or `1-`).

Another example in which 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 clearer.

RM Readability matters,
and nesting works.

31 Extend a list with `cons`

The core of composing elementwise operations.

To build your own `map` function, you need to add to a list. `cons` on a list adds to the front (`cons` on other values creates a `pair`).

```
cons 1 : list 2 3 ;; => list 1 2 3
cons 1 2          ;; => (1 . 2) - also see pair? and assoc
```

```
$1 = (1 2 3)
$2 = (1 . 2)
```

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 ;; restore the order
      else
        loop
          ;; add processed first element to changed
          cons : proc : first elements ;; add processed
               . changed               ;; to changed
          cdr elements ;; drop first element from elements
single-map even? : list 1 2 3
```

```
$1 = (#f #t #f)
```

Repeatedly cons'ing the first element of a list onto a second list and dropping it from the first reverses the element order. It's a core operation, because it's the most efficient operation for Scheme's lists.

32 Mutate partially shared state with `list-set!`

The elements in a list are linked from its start. Different lists can share the same tail when you cons onto the same partial list.

```
define tail ;; the shared tail
  list 3 2 1 ;; 3 2 1
define four ;; an intermediate list
  cons 4 tail ;; 4 3 2 1
define five ;; one more list
  cons 5 four ;; 5 4 3 2 1
define fourtytwo ;; branching off from tail
  cons 42 tail ;; 42 3 2 1
list-set! five 1 "four" ;; change shared state
. five ;; changed directly: 5 four 3 2 1
. four ;; touched indirectly ;; four 3 2 1
. fourtytwo ;; not affected ;; 42 3 2 1
list-set! tail 1 "two" ;; mutating the shared tail
. five ;; 5 four 3 two 1
. four ;; four 3 two 1
. fourtytwo ;; 42 3 two 1
. tail ;; 3 two 1
```

```
$1 = "four"
$2 = (5 "four" 3 2 1)
$3 = ("four" 3 2 1)
$4 = (42 3 2 1)
$5 = "two"
$6 = (5 "four" 3 "two" 1)
$7 = ("four" 3 "two" 1)
$8 = (42 3 "two" 1)
$9 = (3 "two" 1)
```

Mutating shared state often causes mistakes. Use it only when needed.

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

```
list : quote alice
       quote bob
       quote 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 a form with parentheses for display
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
```

```
$1 = (alice bob carol dave)
$2 = "the first"
$3 = "the first"
$4 = (list 1 2 3)
$5 = (1 2 3)
$6 = (1 2 3)
$7 = (1 2 3)
$8 = #t
```

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

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
list-set! mutable-list 1 'a ;; zero-indexed: a replaces 2
. mutable-list
define immutable-list : ' 1 2 3
. immutable-list
list-set! immutable-list 1 'a ;; error!
```

```
$1 = a
$2 = (1 a 3)
$3 = (1 2 3)
ice-9/boot-9.scm:1705:22: 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.
```

34 Apply partial procedures with `srfi :26 cut`

```
import : srfi :26 cut
define : plus-3 number
  + 3 number
map plus-3 : list 1 2 3 ;; => 4 5 6
define plus-3-cut : cut + 3 <> ;; the arg is used at <>
plus-3-cut 9 ;; => + 3 9 => 12

map : cut + 3 <> ;; defined inline
  list 1 2 3 ;; => 4 5 6
map : cut - <> 1 ;; => {<> - 1}
  list 1 2 3 ;; => 0 1 2
map : cut - 1 <> ;; => {1 - <>}
  list 1 2 3 ;; => 0 -1 -2
```

```
$1 = (4 5 6)
$2 = 12
$3 = (4 5 6)
$4 = (0 1 2)
$5 = (0 -1 -2)
```

`cut` enables more concise definition of derived logic. These specialized definitions also help to simplify `and=>`:

```
import : srfi :26 cut
and=> #f : cut + <> 3 ;; #f ;; and=> applies logic, if its
and=> 20 : cut + <> 3 ;; 23 ;; first argument is not #f
```

```
$1 = #f
$2 = 23
```

This method is known in mathematics as "currying".

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

R^{7}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 Vector with `O(1)` random access guarantee.

```
import : scheme base
define vec : list->vector : ' 1 b "third"
. vec
vector-map : λ (element) : cons "el" element
           . vec
vector-ref vec 0 ;; zero-indexed
```

```
$1 = #(1 b "third")
$2 = #(("el" . 1) ("el" . b) ("el" . "third"))
$3 = 1
```

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

```
import : scheme base
define mutable-vector : list->vector : ' 1 b "third"
define literal-vector #(1 b 3)
vector-set! mutable-vector 1 "bee" ;; allowed
vector-set! literal-vector 1 "bee" ;; error
```

```
ice-9/boot-9.scm:1705:22: In procedure raise-exception:
In procedure vector-set!: Wrong type argument in position
↪  1 (expecting mutable vector): #(1 b 3)

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

36 Name structured values with define-record-type

```
import : srfi :9 records

define-record-type <tree>
  make-tree kind height-m weight-kg carbon-kg
  . tree?
  kind tree-kind ;; the kind of tree, e.g. "birch"
  height-m tree-height  ;; the second argument is the
  weight-kg tree-weight ;; name for the logic to get
  carbon-kg tree-carbon ;; the value from the record

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
. birch-young
. birch-old
. birch-weights ;; 90 5301
```

```
$1 = #<<tree> kind: "birch" height-m: 13 weight-kg: 90
↪  carbon-kg: 45>
$2 = #<<tree> kind: "birch" height-m: 30 weight-kg: 5301
↪  carbon-kg: 2650>
$3 = (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.

37 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.w`. Use `define-module` and choose with `#:export` what gets imported:

```
define-module : example trees
              . #:export ;; the following is exported
              birch-young
                . make-tree tree? tree-carbon ;; continued
import : srfi :9 records ;; imports after module
define-record-type <tree> ;; reduced record type
  make-tree carbon-kg
  . tree?
  carbon-kg tree-carbon
define birch-young
  make-tree 45 ;; about 10 years, 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 correctly, use shell-indirection:

```
#!/usr/bin/env bash
exec -a "${0}" guile --language=wisp \
     -L "$(dirname "${0}")" -x .w "${0}" ${@}
;; Wisp execution !#
import : example trees
. birch-young
```

```
$1 = #f
$2 = #<<tree> carbon-kg: 45>
```

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

38 Handle errors using `with-exception-handler`

```
;; unhandled exception stops execution
define : add-5 input
  + 5 input ;; illegal for text
map add-5 : list "five" 6 "seven" ;; see the error
;; check inputs to avoid the exception
define : add-5-if input
  if : number? input
     + 5 input
     . #f
map add-5-if : list "five" 6 "seven"
;; handle exceptions
define : add-5-handler input
  with-exception-handler
    λ (e) : format #t "must be number, is ~S.\n" input
          . #f ;; result in case of error
    λ () : + 5 input
    . #:unwind? #t ;; #t: continue #f: stop
map add-5-handler : list "five" 6 "seven"
```

```
$1 = #f
ice-9/boot-9.scm:1705:22: In procedure raise-exception:
In procedure +: Wrong type argument in position 1: "five"

Entering a new prompt.  Type `,bt' for a backtrace or `,q' to conti
$2 = (#f 11 #f)
must be number, is "five".
must be number, is "seven".
$3 = (#f 11 #f)
```

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

39 Debug with backtraces

To find the cause of an exception, you can use backtraces. When you see an error interactively, you get a backtrace with `,bt`:

```
define : add-5 input
  display : + 5 input ;; illegal for text

add-5 "six"
```

```
ice-9/boot-9.scm:1683:22: In procedure raise-exception:
In procedure +: Wrong type argument in position 1: "six"

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

,bt

```
In current input:
      1:0  1 (add-5 "six")
In ice-9/boot-9.scm:
  1683:22  0 (raise-exception _ #:continuable? _)
```

The error comes from the first item `(add-5 "six")`, and it is thrown in the file `ice-9/boot-9.scm` via `raise-exception`. When the error comes from a file, you also get a file name and line number for the first item. Most backtraces are longer.

The number in square brackets after the interactive error (`[1]`) is your depth in the debugger. You can get one level back with `,q` or `CTRL-D` (when outside the debugger this exits from Guile).

To throw debuggable errors yourself, use `raise-exception` or `scm-error`. Also see the chapter Exceptions in the Guile Reference Manual.

40 Define derived logic structures with `define-syntax-rule`

In `procedures`, arguments are evaluated to their return value before the body runs. `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
```

The result of `pretty-print` is `#<unspecified>`

`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" ;; <- evaluated first
    for-each pretty-print : list args ...
early-printer 1
  pretty-print "second" ;; "second" shown after "Hello"
  . 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`, it uses a pattern with `...`:

`define-syntax-rule : name args ...`

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

The body of `define-syntax-rule` must have only 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.

41 Build value-lists with `quasiquote` and `unquote`

```
define : tree-with-list-cons type height weight
  . "Create a tree with list and cons."
  list : cons 'type type     ;; cons-created pairs are
         cons 'height height ;; more efficient that lists
         cons 'weight weight ;; see pair? and assoc
tree-with-list-cons "birch" 13 90

define : tree-quasiquote type height weight
  . "Create a tree with raw quasiquote and unquote."
  quasiquote
    :
      type . : unquote type
      height . : unquote height
      weight . : unquote weight
tree-quasiquote "birch" 13 90

define : tree-shorthand type height weight
  . "Create a tree with quasiquote/unquote shorthands."
  ` : type . ,type     ;; ` is short for quasiquoted list
      height . ,height ;; , is short for unquote
      weight . ,weight
tree-shorthand "birch" 13 90
```

```
$1 = ((type . "birch") (height . 13) (weight . 90))
$2 = ((type . "birch") (height . 13) (weight . 90))
$3 = ((type . "birch") (height . 13) (weight . 90))
```

These three methods are almost equivalent, except that quasiquoting can create an immutable list, but this is not guaranteed.

```
define three 3
define mutable-list : list 1 2 3
list-set! mutable-list 1 'a ;; zero-indexed
. mutable-list
define immutable-list : ` 1 2 3
list-set! immutable-list 1 'a ;; error!
. immutable-list
define mutable-quasiquoted : ` 1 2 ,three
list-set! mutable-quasiquoted 1 'a ;; currently no error!
. mutable-quasiquoted
```

```
$1 = a
$2 = (1 a 3)
ice-9/boot-9.scm:1705:22: 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.
$3 = (1 2 3)
$4 = a
$5 = (1 a 3)
```

Mutating quasiquoted lists may throw an error in the future:

> A quasiquote expression may return either newly allocated, mutable objects or literal structure for any structure that is constructed at run time … - the standard (r7rs)

42 Merge lists with append or unquote-splicing

```
define birch-carbon/kg '(5000 5301 5500)
define oak-carbon/kg '(7000 7700 8000)
;; append merges lists
append birch-carbon/kg
     . oak-carbon/kg
;; unquote-splicing splices a list into quasiquote (`)
` : unquote-splicing birch-carbon/kg
  unquote-splicing oak-carbon/kg
;; with shorthand ,@, note the leading period (.)
` ,@birch-carbon/kg
  . ,@oak-carbon/kg
```

```
$1 = (5000 5301 5500 7000 7700 8000)
$2 = (5000 5301 5500 7000 7700 8000)
$3 = (5000 5301 5500 7000 7700 8000)
```

Unquote splicing can also insert the result of logic:

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

```
$1 = (0 1 2 3 2 1 0)
```

The shorthand ,@ can be used with parentheses, but the parentheses must come after it and all calls inside must use parentheses:

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

43 Test your code with `srfi 64`

Is your logic 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 ;; #t
  test-error : throw 'wrong-value
  test-end "test-tree-carbon"

define result : run-tests
```

```
*** Entering test group: test-tree-carbon ***
* PASS:
* PASS:
* PASS:
* PASS:
*** Leaving test group: test-tree-carbon ***
*** Test suite finished. ***
*** # of expected passes     : 4
```

You can use this anywhere to guard against mistakes.

For details, see srfi 64. Take care to test edge cases.

44 Document procedures with docstrings

```
define : documented-proc arg
  . "Proc is documented"
  . #f ;; documentation must not be the last element
procedure-documentation documented-proc
;; variables have no docstrings but
;; properties can be set manually.
define variable #f
set-object-property! variable 'documentation
  . "Variable is documented" ;; returns the value it sets
object-property variable 'documentation
```

```
$1 = "Proc is documented"
$2 = "Variable is documented"
$3 = "Variable is documented"
```

You can get the documentation with `help` or `,d` in 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.w, get the docs via

```
wisp2lisp hello.w > hello.scm && \
    guild doc-snarf --texinfo hello.scm
```

45 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:

- The Guile Reference Manual
- The Guile Library
- Scheme Requests for Implementation (SRFI): tagged libraries
- The Scheme standards (RnRS), specifically r7rs-small (pdf)
- A 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 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** `wisp` (the REPL), you can check documentation:

```
help string-append .
```

```
`string-append' is a procedure in the (guile) 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 64.

46 Create a manual with texinfo

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

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

```
\input texinfo
@documentencoding UTF-8
@settitle Hello World
@dircategory Hello World package
@direntry
* Hello: (hello). A hello world package.
@end direntry
@c This is a comment; The Top node is the first page
@node Top
@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
@bye
```

Add a `Makefile` in the doc/ folder. Make sure to indent with tab.

```
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:

```
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` to `makeinfo`.

You can also write an Org Mode document and evaluate `(require 'ox-texinfo)` to activate exporting to texinfo.

47 Track changes with a version tracking system like Mercurial or Git

For convenience always start by initializing a version tracking repository, for example using Mercurial or Git.

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

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.

48 Package with autoconf and automake

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

```
# Project name, version, and contact information.
AC_INIT([hello], [0.0.1], [my-name@example.com])
# Find a supported Guile version and set it as @GUILE@
GUILE_PKG([3.0])
GUILE_PROGS
GUILE_SITE_DIR
AC_PREFIX_PROGRAM([guile])
AM_INIT_AUTOMAKE([gnu])
# create Makefile from Makefile.am
AC_CONFIG_FILES([Makefile])
AC_OUTPUT
```

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

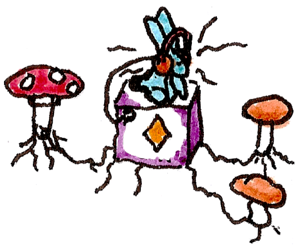
```
bin_SCRIPTS = hello # program name
SUFFIXES = .w .scm .sh
WISP = hello.w # source files
hello: $(WISP)
	echo "#!/usr/bin/env bash" > "$@" && \
	echo 'exec -a "$$0" guile' \
	  '-L "$$(dirname "$$(realpath "$$0")")"' \
	  '-L "$$(dirname "$$(realpath
	  ↪  "$$0")")/../share/guile/site/3.0/"' \
	  '--language=wisp -x .w -s "$$0" "$$@"' \
	  >> "$@" && echo ";; exec done: !#" >> "$@" && \
	cat "$<" >> "$@" && chmod +x "$@"
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) $(WISP:%.w=%.go)
nobase_go_DATA = $(GOBJECTS)
godir=$(libdir)/guile/$(GUILE_EFFECTIVE_VERSION)/site-ccache

# 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 = $(WISP) $(info_TEXINFOS) $(nobase_site_DATA)
↪  AUTHORS ChangeLog
CLEANFILES = $(GOBJECTS) $(wildcard *~)
DISTCLEANFILES = $(bin_SCRIPTS) $(nobase_site_DATA)

# precompile all source files
.w.go:
    GUILE_LOAD_COMPILED_PATH="/home/arne/Schreibtisch/arnebab⌟
    ↪  -org" \
    $(GUILE_TOOLS) compile --from=wisp $(GUILE_WARNINGS) \
       -L "/home/arne/Schreibtisch/arnebab-org" -L
       ↪  "/home/arne/Schreibtisch/arnebab-org" \
       -o "$@" "$<"
```

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
    touch "$@"
    if test -d ".git"; \
        then cd "$(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
autoreconf -i && ./configure && make
#+end_src

* Create a distribution tarball

#+begin_src bash
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.w` file:

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

49 Deploy a project to users

Enable people to access your project as a webserver behind nginx, as a clientside browser-app, or as a 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 ;; these are what the browser sees
      build-response
        . #:headers `((content-type . (text/plain)))
        . #:code 404
      string-append "404 not found: " path ;; content
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:

```
;; file: hoot.w
use-modules : hoot ffi ;; guile specific import

;; the interface
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)

;; your code
append-child! : document-body
  make-text-node "Hello, world!"
```

Transpile with `wisp2lisp` and `guild compile-wasm`. If you run Guix:

```
guix shell guile guile-wisp -- \
  wisp2lisp hoot.w > hoot.scm && \
    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/*hoot/*/re*/{*.js,*.wasm} ./'
```

Load your interface (includes startup time optimizations):

```
/* file: hoot.js */
var f = window.fetch; window.fetch = (inp, ini) => f(inp,
  {credentials: 'include', mode: 'no-cors', ...ini});
window.addEventListener("load", () =>
  fetch("hoot.wasm").then(r => r.arrayBuffer())
    .then(bytes => Scheme.load_main(bytes, {
      user_imports: { // mapped via define-foreign
        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:

```
<!DOCTYPE html> <!-- file: hoot.html -->
<html><head><title>Hello Hoot</title>
<script type="text/javascript" src="reflect.js"></script>
<script type="text/javascript" src="hoot.js"></script>
<link rel="preload" as="fetch" href="hoot.wasm"></link>
<link rel="preload" as="fetch" href="wtf8.wasm"></link>
<link rel="preload" as="fetch" href="reflect.wasm"></link>
</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. Add a `guix.scm`:

```
(import (gnu packages web) (gnu packages base) (gnu packages bash)
        (gnu packages guile) (gnu packages guile-xyz)
        (gnu packages pkg-config) (guix packages) (guix gexp)
        (guix build-system gnu) (guix build-system guile)
        (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)
   (arguments
    (list
     #:modules `((guix build guile-build-system)
                 ,@%default-gnu-imported-modules)
     #:phases
     (with-imported-modules `((guix build guile-build-system)
                              ,@%default-gnu-imported-modules)
       #~(modify-phases %standard-phases
           (add-after 'install 'wrap
             (lambda* (#:key inputs outputs #:allow-other-keys)
               (let ((out (assoc-ref outputs "out"))
                     (effective-version (target-guile-effective-version)))
                 (wrap-program (string-append out "/bin/doctest")
                   `("PATH" ":" prefix
                     ,(map (λ (x) (dirname (search-input-file inputs x)))
                           (list "/bin/guile" "/bin/bash")))
                   `("GUILE_LOAD_PATH" prefix
                     (,(string-append out "/share/guile/site/"
                                      effective-version)
                      ,(getenv "GUILE_LOAD_PATH")))
                   `("GUILE_LOAD_COMPILED_PATH" prefix
                     (,(string-append out "/lib/guile/"
                                  effective-version "/site-ccache")
                      ,(getenv "GUILE_LOAD_COMPILED_PATH"))))))))))
   (propagated-inputs `(("guile" ,guile-3.0)
                        ("pkg-config" ,pkg-config)
                        ("bash" ,bash)
                        ("guile-wisp" ,guile-wisp)
                        ("coreutils" ,coreutils)))
   (home-page "https://hg.sr.ht/~arnebab/guile-doctests")
   (synopsis "Tests in procedure definitions")
   (description "Guile module to keep tests in your procedure definition.")
   (license license:lgpl3+)))

guile-doctests
```

First test building `guix build -f guix.scm`, then test running with `guix shell --pure -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. In 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. Note the `wisp2lisp` call in the `Makefile.am` to prepare the `guix.scm` file.

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.

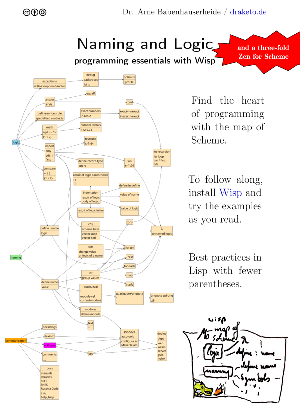
Also see the Map of R^7RS and the Scheme primer to keep learning.

You are ready.

Go and build a project you care about.

List of Links

Free Digital Version of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