

# LUA 5.2 REFERENCE MANUAL

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# 1 · Introduction

Lua is an extension programming language designed to support general procedural programming with data description facilities. It also offers good support for object-oriented programming, functional programming, and data-driven programming. Lua is intended to be used as a powerful, lightweight, embeddable scripting language for any program that needs one. Lua is implemented as a library, written in *clean C*, the common subset of Standard C and C++.

Being an extension language, Lua has no notion of a ‘main’ program: it only works *embedded* in a host client, called the *embedding program* or simply the *host*. The host program can invoke functions to execute a piece of Lua code, can write and read Lua variables, and can register C functions to be called by Lua code. Through the use of C functions, Lua can be augmented to cope with a wide range of different domains, thus creating customized programming languages sharing a syntactical framework. The Lua distribution includes a sample host program called `lua`, which uses the Lua library to offer a complete, standalone Lua interpreter, for interactive or batch use.

Lua is free software, and is provided as usual with no guarantees, as stated in its license. The implementation described in this manual is available at Lua’s official web site, [www.lua.org](http://www.lua.org).

Like any other reference manual, this document is dry in places. For a discussion of the decisions behind the design of Lua, see the technical papers available at Lua’s web site. For a detailed introduction to programming in Lua, see Roberto’s book, *Programming in Lua*.

## 2 · Basic Concepts

This section describes the basic concepts of the language.

### 2.1 · Values and Types

Lua is a *dynamically typed language*. This means that variables do not have types; only values do. There are no type definitions in the language. All values carry their own type.

All values in Lua are *first-class values*. This means that all values can be stored in variables, passed as arguments to other functions, and returned as results.

There are eight basic types in Lua: *nil*, *boolean*, *number*, *string*, *function*, *userdata*, *thread*, and *table*. *Nil* is the type of the value **nil**, whose main property is to be different from any other value; it usually represents the absence of a useful value. *Boolean* is the type of the values **false** and **true**. Both **nil** and **false** make a condition false; any other value makes it true. *Number* represents real (double-precision floating-point) numbers. Operations on numbers follow the same rules of the underlying C implementation, which, in turn, usually follows the IEEE 754 standard. (It is easy to build Lua interpreters that use other internal representations for numbers, such as single-precision floats or long integers; see file `luaconf.h`.) *String* represents immutable sequences

of bytes. Lua is 8-bit clean: strings can contain any 8-bit value, including embedded zeros (`'\0'`).

Lua can call (and manipulate) functions written in Lua and functions written in C (see §3.4.9).

The type *userdata* is provided to allow arbitrary C data to be stored in Lua variables. A userdata value is a pointer to a block of raw memory. There are two kinds of userdata: full userdata, where the block of memory is managed by Lua, and light userdata, where the block of memory is managed by the host. Userdata has no predefined operations in Lua, except assignment and identity test. By using *metatables*, the programmer can define operations for full userdata values (see §2.4). Userdata values cannot be created or modified in Lua, only through the C API. This guarantees the integrity of data owned by the host program.

The type *thread* represents independent threads of execution and it is used to implement coroutines (see §2.6). Do not confuse Lua threads with operating-system threads. Lua supports coroutines on all systems, even those that do not support threads.

The type *table* implements associative arrays, that is, arrays that can be indexed not only with numbers, but with any Lua value except **nil** and NaN (*Not a Number*, a special numeric value used to represent undefined or unrepresentable results, such as 0/0). Tables can be *heterogeneous*; that is, they can contain values of all types (except **nil**). Any key with value **nil** is not considered part of the table. Conversely, any key that is not part of a table has an associated value **nil**.

Tables are the sole data structuring mechanism in Lua; they can be used to represent ordinary arrays, sequences, symbol tables, sets, records, graphs, trees, etc. To represent records, Lua uses the field name as an index. The language supports this representation by providing `a.name` as syntactic sugar for `a["name"]`. There are several convenient ways to create tables in Lua (see §3.4.8).

We use the term *sequence* to denote a table where the set of all positive numeric keys is equal to 1..*n* for some integer *n*, which is called the length of the sequence (see §3.4.6).

Like indices, the values of table fields can be of any type. In particular, because functions are first-class values, table fields can contain functions. Thus tables can also carry *methods* (see §3.4.10).

The indexing of tables follows the definition of raw equality in the language. The expressions `a[i]` and `a[j]` denote the same table element if and only if *i* and *j* are raw equal (that is, equal without metamethods).

Tables, functions, threads, and (full) userdata values are *objects*: variables do not actually contain these values, only references to them. Assignment, parameter passing, and function returns always manipulate references to such values; these operations do not imply any kind of copy.

The library function `type` returns a string describing the type of a given value (see §6.1).

## 2.2 · Environments and the Global Environment

As will be discussed in §3.2 and §3.3.3, any reference to a global name `var` is syntactically translated to `_ENV.var`. Moreover, every chunk is compiled in the scope of an external local variable called `_ENV` (see §3.3.2); so `_ENV` itself is never a global name in a chunk.

Despite the existence of this external `_ENV` variable and the translation of global names, `_ENV` is a completely regular name. In particular, you can define new variables and parameters with that name. Each reference to a global name uses the `_ENV` that is visible at that point in the program, following the usual visibility rules of Lua (see §3.5).

Any table used as the value of `_ENV` is called an *environment*.

Lua keeps a distinguished environment called the *global environment*. This value is kept at a special index in the C registry (see §4.5). In Lua, the variable `_G` is initialized with this same value.

When Lua compiles a chunk, it initializes the value of its `_ENV` upvalue with the global environment (see `load`). Therefore, by default, global variables in Lua code refer to entries in the global environment. Moreover, all standard libraries are loaded in the global environment and several functions there operate on that environment. You can use `load` (or `loadfile`) to load a chunk with a different environment. (In C, you have to load the chunk and then change the value of its first upvalue.)

If you change the global environment in the registry (through C code or the debug library), all chunks loaded after the change will get the new environment. Previously loaded chunks are not affected, however, as each has its own reference to the environment in its `_ENV` variable. Moreover, the variable `_G` (which is stored in the original global environment) is never updated by Lua.

## 2.3 · Error Handling

Because Lua is an embedded extension language, all Lua actions start from C code in the host program calling a function from the Lua library (see `lua_pcall`). Whenever an error occurs during the compilation or execution of a Lua chunk, control returns to the host, which can take appropriate measures (such as printing an error message).

Lua code can explicitly generate an error by calling the `error` function. If you need to catch errors in Lua, you can use `pcall` or `xpcall` to call a given function in *protected mode*.

Whenever there is an error, an *error object* (also called an *error message*) is propagated with information about the error. Lua itself only generates errors where the error object is a string, but programs may generate errors with any value for the error object.

When you use `xpcall` or `lua_pcall`, you may give a *message handler* to be called in case of errors. This function is called with the original error message and returns a new error message. It is called before the error unwinds the stack, so that it can gather more information about the error, for instance by inspecting the stack and creating a stack traceback. This message handler

is still protected by the protected call; so, an error inside the message handler will call the message handler again. If this loop goes on, Lua breaks it and returns an appropriate message.

## 2.4 · Metatables and Metamethods

Every value in Lua can have a *metatable*. This *metatable* is an ordinary Lua table that defines the behavior of the original value under certain special operations. You can change several aspects of the behavior of operations over a value by setting specific fields in its metatable. For instance, when a non-numeric value is the operand of an addition, Lua checks for a function in the field `__add` of the value's metatable. If it finds one, Lua calls this function to perform the addition.

The keys in a metatable are derived from the *event* names; the corresponding values are called *metamethods*. In the previous example, the event is "add" and the metamethod is the function that performs the addition.

You can query the metatable of any value using the `getmetatable` function.

You can replace the metatable of tables using the `pdf-setmetatablesetmetatable` function. You cannot change the metatable of other types from Lua (except by using the debug library); you must use the C API for that.

Tables and full userdata have individual metatables (although multiple tables and userdata can share their metatables). Values of all other types share one single metatable per type; that is, there is one single metatable for all numbers, one for all strings, etc. By default, a value has no metatable, but the string library sets a metatable for the string type (see §6.4).

A metatable controls how an object behaves in arithmetic operations, order comparisons, concatenation, length operation, and indexing. A metatable also can define a function to be called when a userdata or a table is garbage collected. When Lua performs one of these operations over a value, it checks whether this value has a metatable with the corresponding event. If so, the value associated with that key (the metamethod) controls how Lua will perform the operation.

Metatables control the operations listed next. Each operation is identified by its corresponding name. The key for each operation is a string with its name prefixed by two underscores, `__`; for instance, the key for operation 'add' is the string `"__add"`.

The semantics of these operations is better explained by a Lua function describing how the interpreter executes the operation. The code shown here in Lua is only illustrative; the real behavior is hard coded in the interpreter and it is much more efficient than this simulation. All functions used in these descriptions (`rawget`, `tonumber`, etc.) are described in §6.1. In particular, to retrieve the metamethod of a given object, we use the expression

```
metatable(obj)[event]
```

This should be read as

```
rawget(getmetatable(obj) or {}, event)
```

This means that the access to a metamethod does not invoke other metamethods, and access to objects with no metatables does not fail (it simply results in `nil`).

For the unary `-` and `#` operators, the metamethod is called with a dummy second argument. This extra argument is only to simplify Lua's internals; it may be removed in future versions and therefore it is not present in the following code. (For most uses this extra argument is irrelevant.)

- "add": the `+` operation.

The function `getbinhandler` below defines how Lua chooses a handler for a binary operation. First, Lua tries the first operand. If its type does not define a handler for the operation, then Lua tries the second operand.

```
function getbinhandler (op1, op2, event)
    return metatable(op1)[event] or
           metatable(op2)[event]
end
```

By using this function, the behavior of `op1+op2` is

```
function add_event (op1, op2)
    local o1,o2 = tonumber(op1),tonumber(op2)
    if o1 and o2 then -- both are numeric?
        return o1 + o2 -- '+' here is 'add'
    else -- at least one is not numeric
        local h = getbinhandler(op1,op2,"__add")
        if h then
            -- call handler with both operands
            return (h(op1, op2))
        else -- no handler available
            error(...)
        end
    end
end
```

- "sub": the `-` operation. Behavior similar to the "add" operation.
- "mul": the `*` operation. Behavior similar to the "add" operation.
- "div": the `/` operation. Behavior similar to the "add" operation.
- "mod": the `%` operation. Behavior similar to the "add" operation, with the operation `o1 - floor(o1/o2)*o2` as the primitive operation.
- "pow": the `^` (exponentiation) operation. Behavior similar to the "add" operation, with the function `pow` (from the C math library) as the primitive operation.
- "unm": the unary `-` operation.

```
function unm_event (op)
    local o = tonumber(op)
    if o then -- operand is numeric?
        return -o -- '-' here is 'unm'
    else -- the operand is not numeric.
        -- Try to get a handler
        local h = metatable(op).__unm
        if h then
            -- call the handler
            return (h(op))
        else -- no handler available
            error(...)
        end
    end
end
```

```
end
end
• "concat": the .. (concatenation) operation.
function concat_event (op1, op2)
    if (type(op1) == "string" or
        type(op1) == "number") and
        (type(op2) == "string" or
         type(op2) == "number") then
        return op1 .. op2 -- primitive
    else
        local h = getbinhandler(op1,op2,
                                   "__concat")
        if h then
            return (h(op1, op2))
        else
            error(...)
        end
    end
end
```

- "len": the `#` operation.

```
function len_event (op)
    if type(op) == "string" then
        return strlen(op) -- primitive
    else
        local h = metatable(op).__len
        if h then
            return (h(op)) -- call handler
        elseif type(op) == "table" then
            return #op -- primitive
        else -- no handler available: error
            error(...)
        end
    end
end
```

See §3.4.6 for a description of the length of a table.

- "eq": the `==` operation. The `getequalhandler` function defines how Lua chooses a metamethod for equality. A metamethod is selected only when both values being compared have the same type and the same metamethod for the selected operation, and the values are either tables or full userdata.

```
function getequalhandler (op1, op2)
    if type(op1) ~= type(op2) or
        (type(op1) ~= "table" and
         type(op1) ~= "userdata") then
        return nil -- different values
    end
    local mm1 = metatable(op1).__eq
    local mm2 = metatable(op2).__eq
    if mm1 == mm2 then return mm1
    else return nil end
end
```

The 'eq' event is defined as follows:

```
function eq_event (op1, op2)
    if op1 == op2 then -- primitive equal?
        return true -- values are equal
    end
    -- try metamethod
    local h = getequalhandler(op1, op2)
    if h then
        return not not h(op1, op2)
    end
end
```

```

else
    return false
end
end

```

Note that the result is always a boolean.

- "lt": the < operation.

```

function lt_event (op1, op2)
    if type(op1) == "number" and
       type(op2) == "number" then
        return op1 < op2 -- numeric
    elseif type(op1) == "string" and
           type(op2) == "string" then
        return op1 < op2 -- lexicographic
    else
        local h = getbinhandler(op1,op2,"__lt")
        if h then
            return not not h(op1, op2)
        else
            error(...)
        end
    end
end
end

```

Note that the result is always a boolean.

- "le": the <= operation.

```

function le_event (op1, op2)
    if type(op1) == "number" and
       type(op2) == "number" then
        return op1 <= op2 -- numeric
    elseif type(op1) == "string" and
           type(op2) == "string" then
        return op1 <= op2 -- lexicographic
    else
        local h = getbinhandler(op1,op2,"__le")
        if h then
            return not not h(op1, op2)
        else
            h = getbinhandler(op1,op2,"__lt")
            if h then
                return not h(op2, op1)
            else
                error(...)
            end
        end
    end
end
end

```

Note that, in the absence of a "le" metamethod, Lua tries "lt", assuming that  $a \leq b$  is equivalent to  $\text{not } (b < a)$ .

As with the other comparison operators, the result is always a boolean.

- "index": The indexing access `table[key]`. Note that the metamethod is tried only when `key` is not present in `table`. (When `table` is not a table, no key is ever present, so the metamethod is always tried.)

```

function gettable_event (table, key)
    local h
    if type(table) == "table" then
        local v = rawget(table, key)
        -- if key is present, return raw value
        if v ~= nil then return v end
    end
end

```

```

h = metatable(table).__index
if h == nil then return nil end
else
    h = metatable(table).__index
    if h == nil then
        error(...)
    end
end
end
if type(h) == "function" then
    return (h(table, key)) -- call handler
else return h[key] -- or repeat
end
end

```

- "newindex": The indexing assignment `table[key] = value`. Note that the metamethod is tried only when `key` is not present in `table`.

```

function settable_event (table, key, value)
    local h
    if type(table) == "table" then
        local v = rawget(table, key)
        -- if key is present, do raw assignment
        if v ~= nil then
            rawset(table, key, value); return end
        h = metatable(table).__newindex
        if h == nil then
            rawset(table, key, value); return end
        else
            h = metatable(table).__newindex
            if h == nil then
                error(...)
            end
        end
    end
    if type(h) == "function" then
        h(table, key,value) -- call handler
    else h[key] = value -- or repeat
    end
end
end

```

- "call": called when Lua calls a value.

```

function function_event (func, ...)
    if type(func) == "function" then
        return func(...) -- primitive call
    else
        local h = metatable(func).__call
        if h then
            return h(func, ...)
        else
            error(...)
        end
    end
end
end

```

## 2.5 · Garbage Collection

Lua performs automatic memory management. This means that you have to worry neither about allocating memory for new objects nor about freeing it when the objects are no longer needed. Lua manages memory automatically by running a *garbage collector* to collect all *dead objects* (that is, objects that are no longer accessible from Lua). All memory used by Lua is subject to automatic management: strings, tables, userdata, functions, threads, internal structures, etc.

Lua implements an incremental mark-and-sweep collector. It uses two numbers to control its garbage-collection cycles: the *garbage-collector pause* and the *garbage-collector step multiplier*. Both use percentage points as units (e.g., a value of 100 means an internal value of 1).

The garbage-collector pause controls how long the collector waits before starting a new cycle. Larger values make the collector less aggressive. Values smaller than 100 mean the collector will not wait to start a new cycle. A value of 200 means that the collector waits for the total memory in use to double before starting a new cycle.

The garbage-collector step multiplier controls the relative speed of the collector relative to memory allocation. Larger values make the collector more aggressive but also increase the size of each incremental step. Values smaller than 100 make the collector too slow and can result in the collector never finishing a cycle. The default is 200, which means that the collector runs at ‘twice’ the speed of memory allocation.

If you set the step multiplier to a very large number (larger than 10% of the maximum number of bytes that the program may use), the collector behaves like a stop-the-world collector. If you then set the pause to 200, the collector behaves as in old Lua versions, doing a complete collection every time Lua doubles its memory usage.

You can change these numbers by calling `lua_gc` in C or `collectgarbage` in Lua. You can also use these functions to control the collector directly (e.g., stop and restart it).

As an experimental feature in Lua 5.2, you can change the collector’s operation mode from incremental to *generational*. A *generational collector* assumes that most objects die young, and therefore it traverses only young (recently created) objects. This behavior can reduce the time used by the collector, but also increases memory usage (as old dead objects may accumulate). To mitigate this second problem, from time to time the generational collector performs a full collection. Remember that this is an experimental feature; you are welcome to try it, but check your gains.

### 2.5.1 · Garbage-Collection Metamethods

You can set garbage-collector metamethods for tables and, using the C API, for full userdata (see §2.4). These metamethods are also called *finalizers*. Finalizers allow you to coordinate Lua’s garbage collection with external resource management (such as closing files, network or database connections, or freeing your own memory).

For an object (table or userdata) to be finalized when collected, you must *mark* it for finalization.

You mark an object for finalization when you set its metatable and the metatable has a field indexed by the string `__gc`. Note that if you set a metatable without a `__gc` field and later create that field in the metatable, the object will not be marked for finalization. However, after an object is marked, you can freely change the `__gc` field of its metatable.

When a marked object becomes garbage, it is not collected immediately by the garbage collector. Instead, Lua puts it in a list. After the collection, Lua does the

equivalent of the following function for each object in that list:

```
function gc_event (obj)
  local h = metatable(obj).__gc
  if type(h) == "function" then
    h(obj)
  end
end
```

At the end of each garbage-collection cycle, the finalizers for objects are called in the reverse order that they were marked for collection, among those collected in that cycle; that is, the first finalizer to be called is the one associated with the object marked last in the program. The execution of each finalizer may occur at any point during the execution of the regular code.

Because the object being collected must still be used by the finalizer, it (and other objects accessible only through it) must be *resurrected* by Lua. Usually, this resurrection is transient, and the object memory is freed in the next garbage-collection cycle. However, if the finalizer stores the object in some global place (e.g., a global variable), then there is a permanent resurrection. In any case, the object memory is freed only when it becomes completely inaccessible; its finalizer will never be called twice.

When you close a state (see `lua_close`), Lua calls the finalizers of all objects marked for collection, following the reverse order that they were marked. If any finalizer marks new objects for collection during that phase, these new objects will not be finalized.

### 2.5.2 · Weak Tables

A *weak table* is a table whose elements are *weak references*. A weak reference is ignored by the garbage collector. In other words, if the only references to an object are weak references, then the garbage collector will collect that object.

A weak table can have weak keys, weak values, or both. A table with weak keys allows the collection of its keys, but prevents the collection of its values. A table with both weak keys and weak values allows the collection of both keys and values. In any case, if either the key or the value is collected, the whole pair is removed from the table. The weakness of a table is controlled by the `__mode` field of its metatable. If the `__mode` field is a string containing the character ‘k’, the keys in the table are weak. If `__mode` contains ‘v’, the values in the table are weak.

A table with weak keys and strong values is also called an *ephemeron table*. In an ephemeron table, a value is considered reachable only if its key is reachable. In particular, if the only reference to a key comes through its value, the pair is removed.

Any change in the weakness of a table may take effect only at the next collect cycle. In particular, if you change the weakness to a stronger mode, Lua may still collect some items from that table before the change takes effect.

Only objects that have an explicit construction are removed from weak tables. Values, such as numbers and light C functions, are not subject to garbage collection, and therefore are not removed from weak tables (unless

its associated value is collected). Although strings are subject to garbage collection, they do not have an explicit construction, and therefore are not removed from weak tables.

Resurrected objects (that is, objects being finalized and objects accessible only through objects being finalized) have a special behavior in weak tables. They are removed from weak values before running their finalizers, but are removed from weak keys only in the next collection after running their finalizers, when such objects are actually freed. This behavior allows the finalizer to access properties associated with the object through weak tables.

If a weak table is among the resurrected objects in a collection cycle, it may not be properly cleared until the next cycle.

## 2.6 · Coroutines

Lua supports coroutines, also called *collaborative multithreading*. A coroutine in Lua represents an independent thread of execution. Unlike threads in multithread systems, however, a coroutine only suspends its execution by explicitly calling a yield function.

You create a coroutine by calling `coroutine.create`. Its sole argument is a function that is the main function of the coroutine. The `create` function only creates a new coroutine and returns a handle to it (an object of type *thread*); it does not start the coroutine.

You execute a coroutine by calling `coroutine.resume`. When you first call `coroutine.resume`, passing as its first argument a thread returned by `coroutine.create`, the coroutine starts its execution, at the first line of its main function. Extra arguments passed to `coroutine.resume` are passed on to the coroutine main function. After the coroutine starts running, it runs until it terminates or *yields*.

A coroutine can terminate its execution in two ways: normally, when its main function returns (explicitly or implicitly, after the last instruction); and abnormally, if there is an unprotected error. In the first case, `coroutine.resume` returns `true`, plus any values returned by the coroutine main function. In case of errors, `coroutine.resume` returns `false` plus an error message.

A coroutine yields by calling `coroutine.yield`. When a coroutine yields, the corresponding `coroutine.resume` returns immediately, even if the yield happens inside nested function calls (that is, not in the main function, but in a function directly or indirectly called by the main function). In the case of a yield, `coroutine.resume` also returns `true`, plus any values passed to `coroutine.yield`. The next time you resume the same coroutine, it continues its execution from the point where it yielded, with the call to `coroutine.yield` returning any extra arguments passed to `coroutine.resume`.

Like `coroutine.create`, the `coroutine.wrap` function also creates a coroutine, but instead of returning the coroutine itself, it returns a function that, when called, resumes the coroutine. Any arguments passed to this function go as extra arguments to `coroutine.resume`. `coroutine.wrap` returns all the values returned by

`coroutine.resume`, except the first one (the boolean error code). Unlike `coroutine.resume`, `coroutine.wrap` does not catch errors; any error is propagated to the caller.

As an example of how coroutines work, consider the following code:

```
function foo (a)
  print("foo", a)
  return coroutine.yield(2*a)
end

co = coroutine.create(function (a,b)
  print("co-body", a, b)
  local r = foo(a+1)
  print("co-body", r)
  local r,s = coroutine.yield(a+b,a-b)
  print("co-body",r,s)
  return b,"end"
end)

print("main",coroutine.resume(co,1,10))
print("main",coroutine.resume(co,"r"))
print("main",coroutine.resume(co,"x","y"))
print("main",coroutine.resume(co,"x","y"))
```

When you run it, it produces the following output:

```
co-body 1      10
foo      2
main     true   4
co-body r
main     true  11  -9
co-body x      y
main     true  10  end
main     false cannot resume dead coroutine
```

You can also create and manipulate coroutines through the C API: see functions `lua_newthread`, `lua_resume`, and `lua_yield`.

## 3 · The Language

This section describes the lexis, the syntax, and the semantics of Lua. In other words, this section describes which tokens are valid, how they can be combined, and what their combinations mean.

Language constructs will be explained using the usual extended BNF notation, in which `{a}` means 0 or more *a*'s, and `[a]` means an optional *a*. The complete syntax of Lua can be found in §9 at the end of this manual.

### 3.1 · Lexical Conventions

Lua is a free-form language. It ignores spaces (including new lines) and comments between lexical elements (tokens), except as delimiters between names and keywords.

*Names* (also called *identifiers*) in Lua can be any string of letters, digits, and underscores, not beginning with a digit. Identifiers are used to name variables, table fields, and labels.

The following *keywords* are reserved and cannot be used as names:



and	break	do	else	elseif
end	false	for	function	goto
if	in	local	nil	not
or	repeat	return	then	true
until	while			

Lua is a case-sensitive language: `and` is a reserved word, but `And` and `AND` are two different, valid names. As a convention, names starting with an underscore followed by uppercase letters (such as `_VERSION`) are reserved for variables used by Lua.

The following strings denote other tokens:

+	-	*	/	%	^	#
==	~=	<=	>=	<	>	=
(	)	{	}	[	]	::
;	:	,	.	..	...	

*Literal strings* can be delimited by matching single or double quotes, and can contain the following C-like escape sequences: `\a` (bell), `\b` (backspace), `\f` (form feed), `\n` (newline), `\r` (carriage return), `\t` (horizontal tab), `\v` (vertical tab), `\\` (backslash), `\"` (quotation mark [double quote]), and `\'` (apostrophe [single quote]). A backslash followed by a real newline results in a newline in the string. The escape sequence `\z` skips the following span of white-space characters, including line breaks; it is particularly useful to break and indent a long literal string into multiple lines without adding the newlines and spaces into the string contents.

A byte in a literal string can also be specified by its numerical value. This can be done with the escape sequence `\xxx`, where `xx` is a sequence of exactly two hexadecimal digits, or with the escape sequence `\ddd`, where `ddd` is a sequence of up to three decimal digits. (Note that if a decimal escape is to be followed by a digit, it must be expressed using exactly three digits.) Strings in Lua can contain any 8-bit value, including embedded zeros, which can be specified as `\0`.

Literal strings can also be defined using a long format enclosed by *long brackets*. We define an *opening long bracket of level  $n$*  as an opening square bracket followed by  $n$  equal signs followed by another opening square bracket. So, an opening long bracket of level 0 is written as `[`, an opening long bracket of level 1 is written as `[=`, and so on. A *closing long bracket* is defined similarly; for instance, a closing long bracket of level 4 is written as `]====`. A *long literal* starts with an opening long bracket of any level and ends at the first closing long bracket of the same level. It can contain any text except a closing bracket of the proper level. Literals in this bracketed form can run for several lines, do not interpret any escape sequences, and ignore long brackets of any other level. Any kind of end-of-line sequence (carriage return, newline, carriage return followed by newline, or newline followed by carriage return) is converted to a simple newline.

When parsing a from a string source, any byte in a literal string not explicitly affected by the previous rules represents itself. However, Lua opens files for parsing in text mode, and the system file functions may have problems with some control characters. So, it is safer to represent non-text data as a quoted literal with explicit escape sequences for non-text characters.

For convenience, when the opening long bracket is immediately followed by a newline, the newline is not included in the string. As an example, in a system using ASCII (in which `'a'` is coded as 97, newline is coded as 10, and `'1'` is coded as 49), the five literal strings below denote the same string:

```
a = 'alo\n123'
a = "alo\n123\"
a = '\97lo\10\04923'
a = [[alo
123]]
a = [==[
alo
123"]==]
```

A *numerical constant* can be written with an optional fractional part and an optional decimal exponent, marked by a letter `e` or `E`. Lua also accepts hexadecimal constants, which start with `0x` or `0X`. Hexadecimal constants also accept an optional fractional part plus an optional binary exponent, marked by a letter `p` or `P`. Examples of valid numerical constants are

```
3      3.0      3.1416      314.16e-2      0.31416E1
0xff   0x0.1E   0xA23p-4   0X1.921FB54442D18P+1
```

A *comment* starts with a double hyphen (`--`) anywhere outside a string. If the text immediately after `--` is not an opening long bracket, the comment is a *short comment*, which runs until the end of the line. Otherwise, it is a *long comment*, which runs until the corresponding closing long bracket. Long comments are frequently used to disable code temporarily.

## 3.2 · Variables

Variables are places that store values. There are three kinds of variables in Lua: global variables, local variables, and table fields.

A single name can denote a global variable or a local variable (or a function's formal parameter, which is a particular kind of local variable):

```
var ::= Name
```

Names denote identifiers, as defined in §3.1.

Any variable name is assumed to be global unless explicitly declared as a local (see §3.3.7). Local variables are *lexically scoped*: local variables can be freely accessed by functions defined inside their scope (see §3.5).

Before the first assignment to a variable, its value is `nil`.

Square brackets are used to index a table:

```
var ::= prefixexp '[' exp ']'
```

The meaning of accesses to table fields can be changed via metatables. An access to an indexed variable `t[i]` is equivalent to a call `gettable_event(t,i)`. (See §2.4 for a complete description of the `gettable_event` function. This function is not defined or callable in Lua. We use it here only for explanatory purposes.)

The syntax `var.Name` is just syntactic sugar for `var["Name"]`:



`var ::= prefixexp ‘.’ Name`

~~An access to a global variable `x` is equivalent to `_ENV.x`. Due to the way that chunks are compiled, `_ENV` is never a global name (see §2.2).~~

### 3.3 · Statements

Lua supports an almost conventional set of statements, similar to those in Pascal or C. This set includes assignments, control structures, function calls, and variable declarations.

#### 3.3.1 · Blocks

A block is a list of statements, which are executed sequentially:

`block ::= {stat}`

Lua has *empty statements* that allow you to separate statements with semicolons, start a block with a semicolon or write two semicolons in sequence:

`stat ::= ‘;’`

A block can be explicitly delimited to produce a single statement:

`stat ::= do block end`

Explicit blocks are useful to control the scope of variable declarations. Explicit blocks are also sometimes used to add a `return` statement in the middle of another block (see §3.3.4).

#### 3.3.2 · Chunks

The unit of execution of Lua is called a *chunk*. Syntactically, a chunk is simply a block:

`chunk ::= block`

Lua handles a chunk as the body of an anonymous function with a variable number of arguments (see §3.4.10). As such, chunks can define local variables, receive arguments, and return values. ~~Moreover, such anonymous function is compiled as in the scope of an external local variable called `_ENV` (see §2.2). The resulting function always has `_ENV` as its only upvalue, even if it does not use that variable.~~

A chunk can be stored in a file or in a string inside the host program. To execute a chunk, Lua first precompiles the chunk into instructions for a virtual machine, and then it executes the compiled code with an interpreter for the virtual machine.

Chunks can also be precompiled into binary form; see program `luac` for details. Programs in source and compiled forms are interchangeable; Lua automatically detects the file type and acts accordingly.

#### 3.3.3 · Assignment

Lua allows multiple assignments. Therefore, the syntax for assignment defines a list of variables on the left side and a list of expressions on the right side. The elements in both lists are separated by commas:

`stat ::= varlist ‘=’ explist`  
`varlist ::= var {‘,’ var}`  
`explist ::= exp {‘,’ exp}`

Expressions are discussed in §3.4.

Before the assignment, the list of values is *adjusted* to the length of the list of variables. If there are more values than needed, the excess values are thrown away. If there are fewer values than needed, the list is extended with as many `nil`s as needed. If the list of expressions ends with a function call, then all values returned by that call enter the list of values, before the adjustment (except when the call is enclosed in parentheses; see §3.4).

The assignment statement first evaluates all its expressions and only then are the assignments performed. Thus the code

`i = 3`  
`i, a[i] = i+1, 20`

sets `a[3]` to 20, without affecting `a[4]` because the `i` in `a[i]` is evaluated (to 3) before it is assigned 4. Similarly, the line

`x, y = y, x`

exchanges the values of `x` and `y`, and

`x, y, z = y, z, x`

cyclically permutes the values of `x`, `y`, and `z`.

The meaning of assignments to global variables and table fields can be changed via metatables. An assignment to an indexed variable `t[i] = val` is equivalent to `settable_event(t,i,val)`. (See §2.4 for a complete description of the `settable_event` function. This function is not defined or callable in Lua. We use it here only for explanatory purposes.)

~~An assignment to a global variable `x = val` is equivalent to the assignment `_ENV.x = val` (see §2.2).~~

#### 3.3.4 · Control Structures

The control structures `if`, `while`, and `repeat` have the usual meaning and familiar syntax:

`stat ::= while exp do block end`  
`stat ::= repeat block until exp`  
`stat ::= if exp then block`  
          `{elseif exp then block}`  
          `[else block] end`

Lua also has a `for` statement, in two flavors (see §3.3.5).

The condition expression of a control structure can return any value. Both `false` and `nil` are considered false. All values different from `nil` and `false` are considered true (in particular, the number 0 and the empty string are also true).

In the **repeat—until** loop, the inner block does not end at the **until** keyword, but only after the condition. So, the condition can refer to local variables declared inside the loop block.

The **goto** statement transfers the program control to a label. For syntactical reasons, labels in Lua are considered statements too:

```
stat ::= goto Name
stat ::= label
label ::= '::' Name '::'
```

A label is visible in the entire block where it is defined, except inside nested blocks where a label with the same name is defined and inside nested functions. A **goto** may jump to any visible label as long as it does not enter into the scope of a local variable.

Labels and empty statements are called *void statements*, as they perform no actions.

The **break** statement terminates the execution of a **while**, **repeat**, or **for** loop, skipping to the next statement after the loop:

```
stat ::= break
```

A **break** ends the innermost enclosing loop.

The **return** statement is used to return values from a function or a chunk (which is a function in disguise). Functions can return more than one value, so the syntax for the **return** statement is

```
stat ::= return [explist] [';']
```

The **return** statement can only be written as the last statement of a block. If it is really necessary to **return** in the middle of a block, then an explicit inner block can be used, as in the idiom **do return end**, because now **return** is the last statement in its (inner) block.

### 3.3.5 · For Statement

The **for** statement has two forms: one numeric and one generic.

The numeric **for** loop repeats a block of code while a control variable runs through an arithmetic progression. It has the following syntax:

```
stat ::= for Name '=' exp ',', exp [';', exp]
       do block end
```

The **block** is repeated for **name** starting at the value of the first **exp**, until it passes the second **exp** by steps of the third **exp**. More precisely, a **for** statement like

```
for v = e1, e2, e3 do block end
```

is equivalent to the code:

```
do
  local var, limit, step =
    tonumber(e1), tonumber(e2), tonumber(e3)
  if not (var and limit and step)
    then error() end
  while (step > 0 and var <= limit) or
    (step <= 0 and var >= limit) do
    local v = var
```

```
    block
      var = var + step
    end
  end
end
```

Note the following:

- All three control expressions are evaluated only once, before the loop starts. They must all result in numbers.
- **var**, **limit**, and **step** are invisible variables. The names shown here are for explanatory purposes only.
- If the third expression (the step) is absent, then a step of 1 is used.
- You can use **break** to exit a **for** loop.
- The loop variable **v** is local to the loop; you cannot use its value after the **for** ends or is broken. If you need this value, assign it to another variable before breaking or exiting the loop.

The generic **for** statement works over functions, called *iterators*. On each iteration, the iterator function is called to produce a new value, stopping when this new value is **nil**. The generic **for** loop has the following syntax:

```
stat ::= for namelist in explist do block end
namelist ::= Name {',' Name}
```

A **for** statement like

```
for var_1, ..., var_n in explist do block end
```

is equivalent to the code:

```
do
  local f, s, var = explist
  while true do
    local var_1, ..., var_n = f(s, var)
    if var_1 == nil then break end
    var = var_1
    block
  end
end
```

Note the following:

- **explist** is evaluated only once. Its results are an iterator function, a state, and an initial value for the first iterator variable.
- **f**, **s**, and **var** are invisible variables. The names are here for explanatory purposes only.
- You can use **break** to exit a **for** loop.
- The loop variables **var\_i** are local to the loop; you cannot use their values after the **for** ends. If you need these values, then assign them to other variables before breaking or exiting the loop.

### 3.3.6 · Function Calls as Statements

To allow possible side-effects, function calls can be executed as statements:

```
stat ::= functioncall
```

In this case, all returned values are thrown away. Function calls are explained in §3.4.9.

### 3.3.7 · Local Declarations

Local variables can be declared anywhere inside a block. The declaration can include an initial assignment:

```
stat ::= local namelist ['=' explist]
```

If present, an initial assignment has the same semantics of a multiple assignment (see §3.3.3). Otherwise, all variables are initialized with `nil`.

A chunk is also a block (see §3.3.2), and so local variables can be declared in a chunk outside any explicit block.

The visibility rules for local variables are explained in §3.5.

## 3.4 · Expressions

The basic expressions in Lua are the following:

```
exp ::= prefixexp
exp ::= nil | false | true
exp ::= Number
exp ::= String
exp ::= functiondef
exp ::= tableconstructor
exp ::= '...'
exp ::= exp binop exp
exp ::= unop exp
prefixexp ::= var | functioncall | '(' exp ')',
```

Numbers and literal strings are explained in §3.1; variables are explained in §3.2; function definitions are explained in §3.4.10; function calls are explained in §3.4.9; table constructors are explained in §3.4.8. Vararg expressions, denoted by three dots ('...'), can only be used when directly inside a vararg function; they are explained in §3.4.10.

Binary operators comprise arithmetic operators (see §3.4.1), relational operators (see §3.4.3), logical operators (see §3.4.4), and the concatenation operator (see §3.4.5). Unary operators comprise the unary minus (see §3.4.1), the unary `not` (see §3.4.4), and the unary *length operator* (see §3.4.6).

Both function calls and vararg expressions can result in multiple values. If a function call is used as a statement (see §3.3.6), then its return list is adjusted to zero elements, thus discarding all returned values. If an expression is used as the last (or the only) element of a list of expressions, then no adjustment is made (unless the expression is enclosed in parentheses). In all other contexts, Lua adjusts the result list to one element, discarding all values except the first one.

Here are some examples:

```
f()           -- adjusted to 0 results
g(f(),x)      -- f() is adjusted to 1 result
g(x,f())      -- g gets x plus all results
               -- from f()
a,b,c = f(),x  -- f() is adjusted to 1 result
               -- (c gets nil)
a,b = ...     -- a gets the 1st vararg
               -- parameter, b gets the 2nd
               -- (both a and b can get nil
```

```
               -- if there is no corresponding
               -- vararg parameter)
a,b,c = x,f()  -- f() is adjusted to 2 results
a,b,c = f()    -- f() is adjusted to 3 results
return f()     -- returns all results from f()
return ...     -- returns all received vararg
               -- parameters
return x,y,f() -- returns x, y, and all
               -- results from f()
{f()}         -- creates a list with all
               -- results from f()
{...}         -- creates a list with all
               -- vararg parameters
{f(),nil}     -- f() is adjusted to 1 result
```

Any expression enclosed in parentheses always results in only one value. Thus, `(f(x,y,z))` is always a single value, even if `f` returns several values. (The value of `(f(x,y,z))` is the first value returned by `f` or `nil` if `f` does not return any values.)

### 3.4.1 · Arithmetic Operators

Lua supports the usual arithmetic operators: the binary `+` (addition), `-` (subtraction), `*` (multiplication), `/` (division), `%` (modulo), and `^` (exponentiation); and unary `-` (mathematical negation). If the operands are numbers, or strings that can be converted to numbers (see §3.4.2), then all operations have the usual meaning. Exponentiation works for any exponent. For instance, `x-0.5` computes the inverse of the square root of `x`. Modulo is defined as

```
a % b == a - math.floor(a/b)*b
```

That is, it is the remainder of a division that rounds the quotient towards minus infinity.

### 3.4.2 · Coercion

Lua provides automatic conversion between string and number values at run time. Any arithmetic operation applied to a string tries to convert this string to a number, following the rules of the Lua lexer. (The string may have leading and trailing spaces and a sign.) Conversely, whenever a number is used where a string is expected, the number is converted to a string, in a reasonable format. For complete control over how numbers are converted to strings, use the `format` function from the string library (see `string.format`).

### 3.4.3 · Relational Operators

The relational operators in Lua are

```
==    ~=    <    >    <=    >=
```

These operators always result in `false` or `true`.

Equality (`==`) first compares the type of its operands. If the types are different, then the result is `false`. Otherwise, the values of the operands are compared. Numbers and strings are compared in the usual way. Tables, userdata, and threads are compared by reference: two objects are considered equal only if they are the same object.

Every time you create a new object (a table, userdata, or thread), this new object is different from any previously existing object. Closures with the same reference are always equal. Closures with any detectable difference (different behavior, different definition) are always different.

You can change the way that Lua compares tables and userdata by using the "eq" metamethod (see §2.4).

The conversion rules of §3.4.2 do not apply to equality comparisons. Thus, "0"==0 evaluates to **false**, and `t[0]` and `t["0"]` denote different entries in a table.

The `~=` operator is the negation of equality (`==`).

The order operators work as follows. If both arguments are numbers, then they are compared as such. Otherwise, if both arguments are strings, then their values are compared according to the current locale. Otherwise, Lua tries to call the "lt" or the "le" metamethod (see §2.4). A comparison `a>b` is translated to `b<a` and `a>=b` is translated to `b<=a`.

### 3.4.4 · Logical Operators

The logical operators in Lua are **and**, **or**, and **not**. Like the control structures (see §3.3.4), all logical operators consider both **false** and **nil** as false and anything else as true.

The negation operator **not** always returns **false** or **true**. The conjunction operator **and** returns its first argument if this value is **false** or **nil**; otherwise, **and** returns its second argument. The disjunction operator **or** returns its first argument if this value is different from **nil** and **false**; otherwise, **or** returns its second argument. Both **and** and **or** use short-cut evaluation; that is, the second operand is evaluated only if necessary. Here are some examples:

```
10 or 20      --> 10
10 or error() --> 10
nil or "a"    --> "a"
nil and 10    --> nil
false and error() --> false
false and nil  --> false
false or nil   --> nil
10 and 20     --> 20
```

(In this manual, `-->` indicates the result of the preceding expression.)

### 3.4.5 · Concatenation

The string concatenation operator in Lua is denoted by two dots ('..'). If both operands are strings ~~or numbers~~, then they are converted to strings according to the rules mentioned in §3.4.2. Otherwise, the `__concat` metamethod is called (see §2.4).

### 3.4.6 · The Length Operator

The length operator is denoted by the unary prefix operator `#`. The length of a string is its number of bytes (that is, the usual meaning of string length when each character is one byte).

A program can modify the behavior of the length operator for any value but strings through the `__len` metamethod (see §2.4).

Unless a `__len` metamethod is given, the length of a table `t` is only defined if the table is a *sequence*, that is, the set of its positive numeric keys is equal to `1..n` for some integer `n`. In that case, `n` is its length. Note that a table like

```
{10, 20, nil, 40}
```

is not a sequence, because it has the key 4 but does not have the key 3. (So, there is no `n` such that the set `1..n` is equal to the set of positive numeric keys of that table.) Note, however, that non-numeric keys do not interfere with whether a table is a sequence.

### 3.4.7 · Precedence

Operator precedence in Lua follows the table below, from lower to higher priority:

or					
and					
<	>	<=	>=	~=	==
..					
+	-				
*	/	%			
not	#	- (unary)			
^					

As usual, you can use parentheses to change the precedences of an expression. The concatenation ('..') and exponentiation ('^') operators are right associative. All other binary operators are left associative.

### 3.4.8 · Table Constructors

Table constructors are expressions that create tables. Every time a constructor is evaluated, a new table is created. A constructor can be used to create an empty table or to create a table and initialize some of its fields. The general syntax for constructors is

```
tableconstructor ::= '{' [fieldlist] '}'
fieldlist ::= field {fieldsep field}
               [fieldsep]
field ::= '[' exp ']' '=' exp | Name '=' exp
               | exp
fieldsep ::= ',' | ';' ;
```

Each field of the form `[exp1] = exp2` adds to the new table an entry with key `exp1` and value `exp2`. A field of the form `name = exp` is equivalent to `["name"] = exp`. Finally, fields of the form `exp` are equivalent to `[i] = exp`, where `i` are consecutive numerical integers, starting with 1. Fields in the other formats do not affect this counting. For example,

```
a = { [f(1)] = g; "x", "y"; x = 1, f(x),
      [30] = 23; 45 }
```

is equivalent to

```

do
  local t = {}
  t[f(1)] = g
  t[1] = "x"      -- 1st exp
  t[2] = "y"      -- 2nd exp
  t.x = 1         -- t["x"] = 1
  t[3] = f(x)     -- 3rd exp
  t[30] = 23
  t[4] = 45       -- 4th exp
  a = t
end

```

If the last field in the list has the form `exp` and the expression is a function call or a vararg expression, then all values returned by this expression enter the list consecutively (see §3.4.9).

The field list can have an optional trailing separator, as a convenience for machine-generated code.

### 3.4.9 · Function Calls

A function call in Lua has the following syntax:

```
functioncall ::= prefixexp args
```

In a function call, first `prefixexp` and `args` are evaluated. If the value of `prefixexp` has type *function*, then this function is called with the given arguments. Otherwise, the `prefixexp` "call" metamethod is called, having as first parameter the value of `prefixexp`, followed by the original call arguments (see §2.4).

The form

```
functioncall ::= prefixexp ':' Name args
```

can be used to call "methods". A call `v:name(args)` is syntactic sugar for `v.name(v,args)`, except that `v` is evaluated only once.

Arguments have the following syntax:

```

args ::= '(' [explist] ')'
args ::= tableconstructor
args ::= String

```

All argument expressions are evaluated before the call. A call of the form `f{fields}` is syntactic sugar for `f({fields})`; that is, the argument list is a single new table. A call of the form `f'string'` (or `f"string"` or `f[[string]]`) is syntactic sugar for `f('string')`; that is, the argument list is a single literal string.

A call of the form `return functioncall` is called a *tail call*. Lua implements *proper tail calls* (or *proper tail recursion*): in a tail call, the called function reuses the stack entry of the calling function. Therefore, there is no limit on the number of nested tail calls that a program can execute. However, a tail call erases any debug information about the calling function. Note that a tail call only happens with a particular syntax, where the `return` has one single function call as argument; this syntax makes the calling function return exactly the returns of the called function. So, none of the following examples are tail calls:

```

return (f(x))      -- results adjusted to 1
return 2*f(x)

```

```

return x,f(x)      -- additional results
f(x); return       -- results discarded
return x or f(x)   -- results adjusted to 1

```

### 3.4.10 · Function Definitions

The syntax for function definition is

```

functiondef ::= function funcbody
funcbody ::= '(' [parlist] ')' block end

```

The following syntactic sugar simplifies function definitions:

```

stat ::= function funcname funcbody
stat ::= local function Name funcbody
funcname ::= Name {'.' Name} [':' Name]

```

The statement

```
function f () body end
```

translates to

```
f = function () body end
```

The statement

```
function t.a.b.c.f () body end
```

translates to

```
t.a.b.c.f = function () body end
```

The statement

```
local function f () body end
```

translates to

```
local f; f = function () body end
```

not to

```
local f = function () body end
```

(This only makes a difference when the body of the function contains references to `f`.)

A function definition is an executable expression, whose value has type *function*. When Lua precompiles a chunk, all its function bodies are precompiled too. Then, whenever Lua executes the function definition, the function is *instantiated* (or *closed*). This function instance (or *closure*) is the final value of the expression.

Parameters act as local variables that are initialized with the argument values:

```
parlist ::= namelist [',' '...'] | '...'
```

When a function is called, the list of arguments is adjusted to the length of the list of parameters, unless the function is a *vararg function*, which is indicated by three dots (`'...'`) at the end of its parameter list. A vararg function does not adjust its argument list; instead, it collects all extra arguments and supplies them to the function through a *vararg expression*, which is also written as three dots. The value of this expression is a list of all actual extra arguments, similar to a function with

multiple results. If a vararg expression is used inside another expression or in the middle of a list of expressions, then its return list is adjusted to one element. If the expression is used as the last element of a list of expressions, then no adjustment is made (unless that last expression is enclosed in parentheses).

As an example, consider the following definitions:

```
function f(a, b) end
function g(a, b, ...) end
function r() return 1,2,3 end
```

Then we have the following mapping from arguments to parameters and to the vararg expression:

CALL	PARAMETERS
-----	-----
f(3)	a=3, b=nil
f(3, 4)	a=3, b=4
f(3, 4, 5)	a=3, b=4
f(r(), 10)	a=1, b=10
f(r())	a=1, b=2
g(3)	a=3, b=nil, ... --> (nothing)
g(3, 4)	a=3, b=4, ... --> (nothing)
g(3, 4, 5, 8)	a=3, b=4, ... --> 5 8
g(5, r())	a=5, b=1, ... --> 2 3

Results are returned using the `return` statement (see §3.3.4). If control reaches the end of a function without encountering a `return` statement, then the function returns with no results.

There is a system-dependent limit on the number of values that a function may return. This limit is guaranteed to be larger than 1000.

The colon syntax is used for defining *methods*, that is, functions that have an implicit extra parameter `self`. Thus, the statement

```
function t.a.b.c:f (params) body end
```

is syntactic sugar for

```
t.a.b.c.f = function (self, params) body end
```

### 3.5 · Visibility Rules

Lua is a lexically scoped language. The scope of a local variable begins at the first statement after its declaration and lasts until the last non-void statement of the innermost block that includes the declaration. Consider the following example:

```
x = 10                -- global variable
do                    -- new block
  local x = x          -- new 'x', with value 10
  print(x)             --> 10
  x = x+1
  do                  -- another block
    local x = x+1      -- another 'x'
    print(x)           --> 12
  end
  print(x)            --> 11
end
print(x)              --> 10 (the global one)
```

Notice that, in a declaration like `local x = x`, the new `x` being declared is not in scope yet, and so the second `x` refers to the outside variable.

Because of the lexical scoping rules, local variables can be freely accessed by functions defined inside their scope. A local variable used by an inner function is called an *up-value*, or *external local variable*, inside the inner function.

Notice that each execution of a `local` statement defines new local variables. Consider the following example:

```
a = {}
local x = 20
for i=1,10 do
  local y = 0
  a[i] = function () y=y+1; return x+y end
end
```

The loop creates ten closures (that is, ten instances of the anonymous function). Each of these closures uses a different `y` variable, while all of them share the same `x`.

## 4 · The Application Program Interface

This section describes the C API for Lua, that is, the set of C functions available to the host program to communicate with Lua. All API functions and related types and constants are declared in the header file `lua.h`.

Even when we use the term "function", any facility in the API may be provided as a macro instead. Except where stated otherwise, all such macros use each of their arguments exactly once (except for the first argument, which is always a Lua state), and so do not generate any hidden side-effects.

As in most C libraries, the Lua API functions do not check their arguments for validity or consistency. However, you can change this behavior by compiling Lua with the macro `LUA_USE_APICHECK` defined.

### 4.1 · The Stack

Lua uses a *virtual stack* to pass values to and from C. Each element in this stack represents a Lua value (`nil`, number, string, etc.).

Whenever Lua calls C, the called function gets a new stack, which is independent of previous stacks and of stacks of C functions that are still active. This stack initially contains any arguments to the C function and it is where the C function pushes its results to be returned to the caller (see `lua_CFunction`).

For convenience, most query operations in the API do not follow a strict stack discipline. Instead, they can refer to any element in the stack by using an index. A positive index represents an absolute stack position (starting at 1); a negative index represents an offset relative to the top of the stack. More specifically, if the stack has *n* elements, then index 1 represents the first element (that is, the element that was pushed onto the stack first) and index *n* represents the last element; index -1 also represents the last element (that is, the element at the top) and index -*n* represents the first element.

---

```
void luaL_requiref
    (lua_State *L, const char *modname,
     lua_CFunction openf, int glb);
```

---

Calls function `openf` with string `modname` as an argument and sets the call result in `package.loaded[modname]`, as if that function has been called through `require`.

If `glb` is true, also stores the result into global `modname`. Leaves a copy of that result on the stack.

---

```
luaL_setfuncs _____ [-nup, +0, e]
```

---

```
void luaL_setfuncs
    (lua_State *L, const luaL_Reg *l, int nup);
```

---

Registers all functions in the array `l` (see `luaL_Reg`) into the table on the top of the stack (below optional upvalues, see next).

When `nup` is not zero, all functions are created sharing `nup` upvalues, which must be previously pushed on the stack on top of the library table. These values are popped from the stack after the registration.

---

```
luaL_setmetatable _____ [-0, +0, -]
```

---

```
void luaL_setmetatable (lua_State *L,
                        const char *tname);
```

---

Sets the metatable of the object at the top of the stack as the metatable associated with name `tname` in the registry (see `luaL_newmetatable`).

---

```
luaL_testudata _____ [-0, +0, e]
```

---

```
void *luaL_testudata (lua_State *L, int arg,
                     const char *tname);
```

---

This function works like `luaL_checkudata`, except that, when the test fails, it returns `NULL` instead of throwing an error.

---

```
luaL_tolstring _____ [-0, +1, e]
```

---

```
const char *luaL_tolstring
    (lua_State *L, int idx, size_t *len);
```

---

Converts any Lua value at the given acceptable index to a C string in a reasonable format. The resulting string is pushed onto the stack and also returned by the function. If `len` is not `NULL`, the function also sets `*len` with the string length.

If the value has a metatable with a `"__tostring"` field, then `luaL_tolstring` calls the corresponding metamethod with the value as argument, and uses the result of the call as its result.

---

```
luaL_traceback _____ [-0, +1, e]
```

---

```
void luaL_traceback
    (lua_State *L, lua_State *L1,
     const char *msg, int level);
```

---

Creates and pushes a traceback of the stack `L1`. If `msg` is not `NULL` it is appended at the beginning of the traceback. The `level` parameter tells at which level to start the traceback.

---

```
luaL_typename _____ [-0, +0, -]
```

---

```
const char *luaL_typename (lua_State *L,
                           int index);
```

---

Returns the name of the type of the value at the given index.

---

```
luaL_unref _____ [-0, +0, -]
```

---

```
void luaL_unref (lua_State *L, int t, int ref);
```

---

Releases reference `ref` from the table at index `t` (see `luaL_ref`). The entry is removed from the table, so that the referred object can be collected. The reference `ref` is also freed to be used again.

If `ref` is `LUA_NOREF` or `LUA_REFNIL`, `luaL_unref` does nothing.

---

```
luaL_where _____ [-0, +1, e]
```

---

```
void luaL_where (lua_State *L, int lvl);
```

---

Pushes onto the stack a string identifying the current position of the control at level `lvl` in the call stack. Typically this string has the following format:

```
chunkname:currentline:
```

Level 0 is the running function, level 1 is the function that called the running function, etc.

This function is used to build a prefix for error messages.

---

## 6 · Standard Libraries

The standard Lua libraries provide useful functions that are implemented directly through the C API. Some of these functions provide essential services to the language (e.g., `type` and `getmetatable`); others provide access to "outside" services (e.g., I/O); and others could be implemented in Lua itself, but are quite useful or have critical performance requirements that deserve an implementation in C (e.g., `table.sort`).

All libraries are implemented through the official C API and are provided as separate C modules. Currently, Lua has the following standard libraries:

- basic library (§6.1);
- coroutine library (§6.2);
- package library (§6.3);
- string manipulation (§6.4);
- table manipulation (§6.5);
- mathematical functions (§6.6) (sin, log, etc.);
- bitwise operations (§6.7);
- input and output (§6.8);
- operating system facilities (§6.9);
- debug facilities (§6.10).



Except for the basic and the package libraries, each library provides all its functions as fields of a global table or as methods of its objects.

To have access to these libraries, the C host program should call the `luaL_openlibs` function, which opens all standard libraries. Alternatively, the host program can open them individually by using `luaL_requiref` to call `luaopen_base` (for the basic library), `luaopen_package` (for the package library), `luaopen_coroutine` (for the coroutine library), `luaopen_string` (for the string library), `luaopen_table` (for the table library), `luaopen_math` (for the mathematical library), `luaopen_bit32` (for the bit library), `luaopen_io` (for the I/O library), `luaopen_os` (for the Operating System library), and `luaopen_debug` (for the debug library). These functions are declared in `luaolib.h`.

## 6.1 · Basic Functions

The basic library provides core functions to Lua. If you do not include this library in your application, you should check carefully whether you need to provide implementations for some of its facilities.

---

**assert** (*v* [, *message*])

Issues an error when the value of its argument *v* is false (i.e., `nil` or `false`); otherwise, returns all its arguments. *message* is an error message; when absent, it defaults to "assertion failed!"

---

**collectgarbage** ([*opt* [, *arg*]])

This function is a generic interface to the garbage collector. It performs different functions according to its first argument, *opt*:

- **"collect"**: performs a full garbage-collection cycle. This is the default option.
- **"stop"**: stops automatic execution of the garbage collector. The collector will run only when explicitly invoked, until a call to restart it.
- **"restart"**: restarts automatic execution of the garbage collector.
- **"count"**: returns the total memory in use by Lua (in Kbytes) and a second value with the total memory in bytes modulo 1024. The first value has a fractional part, so the following equality is always true:  
`k,b = collectgarbage("count")`  
`assert(k*1024 == math.floor(k)*1024+b)`  
 (The second result is useful when Lua is compiled with a non floating-point type for numbers.)
- **"step"**: performs a garbage-collection step. The step "size" is controlled by *arg* (larger values mean more steps) in a non-specified way. If you want to control the step size you must experimentally tune the value of *arg*. Returns `true` if the step finished a collection cycle.
- **"setpause"**: sets *arg* as the new value for the *pause* of the collector (see §2.5). Returns the previous value for *pause*.

- **"setstepmul"**: sets *arg* as the new value for the *step multiplier* of the collector (see §2.5). Returns the previous value for *step*.
- **"isrunning"**: returns a boolean that tells whether the collector is running (i.e., not stopped).
- **"generational"**: changes the collector to generational mode. This is an experimental feature (see §2.5).
- **"incremental"**: changes the collector to incremental mode. This is the default mode.

---

**dofile** ([*filename*])

Opens the named file and executes its contents as a Lua chunk. When called without arguments, **dofile** executes the contents of the standard input (`stdin`). Returns all values returned by the chunk. In case of errors, **dofile** propagates the error to its caller (that is, **dofile** does not run in protected mode).

---

**error** (*message* [, *level*])

Terminates the last protected function called and returns *message* as the error message. Function **error** never returns.

Usually, **error** adds some information about the error position at the beginning of the message, if the message is a string. The *level* argument specifies how to get the error position. With level 1 (the default), the error position is where the **error** function was called. Level 2 points the error to where the function that called **error** was called; and so on. Passing a level 0 avoids the addition of error position information to the message.

---

**\_G**

A global variable (not a function) that holds the global environment (see §2.2). Lua itself does not use this variable; changing its value does not affect any environment, nor vice-versa.

---

**getmetatable** (*object*)

If *object* does not have a metatable, returns `nil`. Otherwise, if the object's metatable has a `"__metatable"` field, returns the associated value. Otherwise, returns the metatable of the given object.

---

**ipairs** (*t*)

If *t* has a metamethod `__ipairs`, calls it with *t* as argument and returns the first three results from the call.

Otherwise, returns three values: an iterator function, the table *t*, and 0, so that the construction

```
for i,v in ipairs(t) do body end
```

will iterate over the pairs (1,*t*[1]), (2,*t*[2]), ..., up to the first integer key absent from the table.

---

**load** (*ld* [, *source* [, *mode* [, *env*]])

Loads a chunk.

If `ld` is a string, the chunk is this string. If `ld` is a function, `load` calls it repeatedly to get the chunk pieces. Each call to `ld` must return a string that concatenates with previous results. A return of an empty string, `nil`, or no value signals the end of the chunk.

If there are no syntactic errors, returns the compiled chunk as a function; otherwise, returns `nil` plus the error message.

If the resulting function has upvalues, the first upvalue is set to the value of the global environment or to `env`, if that parameter is given. ~~When loading main chunks, the first upvalue will be the `_ENV` variable (see §2.2).~~

`source` is used as the source of the chunk for error messages and debug information (see §4.9). When absent, it defaults to `ld`, if `ld` is a string, or to `=(load)` otherwise.

The string `mode` controls whether the chunk can be text or binary (that is, a precompiled chunk). It may be the string `"b"` (only binary chunks), `"t"` (only text chunks), or `"bt"` (both binary and text). The default is `"bt"`.

---

`loadfile ([filename [, mode [, env]]])`

Similar to `load`, but gets the chunk from file `filename` or from the standard input, if no file name is given.

---

`next (table [, index])`

Allows a program to traverse all fields of a table. Its first argument is a table and its second argument is an index in this table. `next` returns the next index of the table and its associated value. When called with `nil` as its second argument, `next` returns an initial index and its associated value. When called with the last index, or with `nil` in an empty table, `next` returns `nil`. If the second argument is absent, then it is interpreted as `nil`. In particular, you can use `next(t)` to check whether a table is empty.

The order in which the indices are enumerated is not specified, *even for numeric indices*. (To traverse a table in numeric order, use a numerical `for`.)

The behavior of `next` is undefined if, during the traversal, you assign any value to a non-existent field in the table. You may however modify existing fields. In particular, you may clear existing fields.

---

`pairs (t)`

If `t` has a metamethod `__pairs`, calls it with `t` as argument and returns the first three results from the call.

Otherwise, returns three values: the `next` function, the table `t`, and `nil`, so that the construction

```
for k,v in pairs(t) do body end
```

will iterate over all key—value pairs of table `t`.

See function `next` for the caveats of modifying the table during its traversal.

---

`pcall (f [, arg1, ...])`

Calls function `f` with the given arguments in *protected mode*. This means that any error inside `f` is not prop-

agated; instead, `pcall` catches the error and returns a status code. Its first result is the status code (a boolean), which is true if the call succeeds without errors. In such case, `pcall` also returns all results from the call, after this first result. In case of any error, `pcall` returns `false` plus the error message.

---

`print (...)`

Receives any number of arguments and prints their values to `stdout`, using the `tostring` function to convert each argument to a string. `print` is not intended for formatted output, but only as a quick way to show a value, for instance for debugging. For complete control over the output, use `string.format` and `io.write`.

---

`rawequal (v1, v2)`

Checks whether `v1` is equal to `v2`, without invoking any metamethod. Returns a boolean.

---

`rawget (table, index)`

Gets the real value of `table[index]`, without invoking any metamethod. `table` must be a table; `index` may be any value.

---

`rawlen (v)`

Returns the length of the object `v`, which must be a table or a string, without invoking any metamethod. Returns an integer number.

---

`rawset (table, index, value)`

Sets the real value of `table[index]` to `value`, without invoking any metamethod. `table` must be a table, `index` any value different from `nil` and `NaN`, and `value` any Lua value.

This function returns `table`.

---

`select (index, ...)`

If `index` is a number, returns all arguments after argument number `index`; a negative number indexes from the end (-1 is the last argument). Otherwise, `index` must be the string `"#"`, and `select` returns the total number of extra arguments it received.

---

`setmetatable (table, metatable)`

Sets the metatable for the given table. (You cannot change the metatable of other types from Lua, only from C.) If `metatable` is `nil`, removes the metatable of the given table. If the original metatable has a `"__metatable"` field, raises an error.

This function returns `table`.

---

`tonumber (e [, base])`

When called with no `base`, `tonumber` tries to convert its argument to a number. If the argument is already a number or a string convertible to a number (see §3.4.2),

then `tonumber` returns this number; otherwise, it returns `nil`.

When called with `base`, then `e` should be a string to be interpreted as an integer numeral in that base. The base may be any integer between 2 and 36, inclusive. In bases above 10, the letter 'A' (in either upper or lower case) represents 10, 'B' represents 11, and so forth, with 'Z' representing 35. If the string `e` is not a valid numeral in the given base, the function returns `nil`.

---

#### `tostring (v)`

Receives a value of any type and converts it to a string in a reasonable format. (For complete control of how numbers are converted, use `string.format`.)

If the metatable of `v` has a `"__tostring"` field, then `tostring` calls the corresponding value with `v` as argument, and uses the result of the call as its result.

---

#### `type (v)`

Returns the type of its only argument, coded as a string. The possible results of this function are `"nil"` (a string, not the value `nil`), `"number"`, `"string"`, `"boolean"`, `"table"`, `"function"`, `"thread"`, and `"userdata"`.

---

#### `_VERSION`

A global variable (not a function) that holds a string containing the current interpreter version. The current contents of this variable is `"Lua 5.2"`.

---

#### `xpcall (f, msgh [, arg1, ...])`

This function is similar to `pcall`, except that it sets a new message handler `msgh`.

## 6.2 · Coroutine Manipulation

The operations related to coroutines comprise a sub-library of the basic library and come inside the table `coroutine`. See §2.6 for a general description of coroutines.

---

#### `coroutine.create (f)`

Creates a new coroutine, with body `f`. `f` must be a Lua function. Returns this new coroutine, an object with type `"thread"`.

---

#### `coroutine.resume (co [, val1, ...])`

Starts or continues the execution of coroutine `co`. The first time you resume a coroutine, it starts running its body. The values `val1, ...` are passed as the arguments to the body function. If the coroutine has yielded, `resume` restarts it; the values `val1, ...` are passed as the results from the yield.

If the coroutine runs without any errors, `resume` returns `true` plus any values passed to `yield` (if the coroutine yields) or any values returned by the body function (if the coroutine terminates). If there is any error, `resume` returns `false` plus the error message.

---

#### `coroutine.running ()`

Returns the running coroutine plus a boolean, `true` when the running coroutine is the main one.

---

#### `coroutine.status (co)`

Returns the status of coroutine `co`, as a string: `"running"`, if the coroutine is running (that is, it called `status`); `"suspended"`, if the coroutine is suspended in a call to `yield`, or if it has not started running yet; `"normal"` if the coroutine is active but not running (that is, it has resumed another coroutine); and `"dead"` if the coroutine has finished its body function, or if it has stopped with an error.

---

#### `coroutine.wrap (f)`

Creates a new coroutine, with body `f`. `f` must be a Lua function. Returns a function that resumes the coroutine each time it is called. Any arguments passed to the function behave as the extra arguments to `resume`. Returns the same values returned by `resume`, except the first boolean. In case of error, propagates the error.

---

#### `coroutine.yield (...)`

Suspends the execution of the calling coroutine. Any arguments to `yield` are passed as extra results to `resume`.

## 6.3 · Modules

The package library provides basic facilities for loading modules in Lua. It exports one function directly in the global environment: `require`. Everything else is exported in a table `package`.

---

#### `require (modname)`

Loads the given module. The function starts by looking into the `package.loaded` table to determine whether `modname` is already loaded. If it is, then `require` returns the value stored at `package.loaded[modname]`. Otherwise, it tries to find a *loader* for the module.

To find a loader, `require` is guided by the `package.searchers` sequence. By changing this sequence, we can change how `require` looks for a module. The following explanation is based on the default configuration for `package.searchers`.

First `require` queries `package.preload[modname]`. If it has a value, this value (which should be a function) is the loader. Otherwise `require` searches for a Lua loader using the path stored in `package.path`. If that also fails, it searches for a C loader using the path stored in `package.cpath`. If that also fails, it tries an *all-in-one* loader (see `package.searchers`).

Once a loader is found, `require` calls the loader with two arguments: `modname` and an extra value dependent on how it got the loader. (If the loader came from a file, this extra value is the file name.) If the loader returns any non-`nil` value, `require` assigns the returned value to `package.loaded[modname]`. If the loader does not

return a non-nil value and has not assigned any value to `package.loaded[modname]`, then `require` assigns `true` to this entry. In any case, `require` returns the final value of `package.loaded[modname]`.

If there is any error loading or running the module, or if it cannot find any loader for the module, then `require` raises an error.

---

#### `package.config`

A string describing some compile-time configurations for packages. This string is a sequence of lines:

- The first line is the directory separator string. Default is `'\'` for Windows and `'/'` for all other systems.
- The second line is the character that separates templates in a path. Default is `'.'`.
- The third line is the string that marks the substitution points in a template. Default is `'?'`.
- The fourth line is a string that, in a path in Windows, is replaced by the executable's directory. Default is `'!'`.
- The fifth line is a mark to ignore all text before it when building the `luaopen_` function name. Default is `'-'`.

---

#### `package.cpath`

The path used by `require` to search for a C loader.

Lua initializes the C path `package.cpath` in the same way it initializes the Lua path `package.path`, using the environment variable `LUA_CPATH_5_2` or the environment variable `LUA_CPATH` or a default path defined in `luaconf.h`.

---

#### `package.loaded`

A table used by `require` to control which modules are already loaded. When you require a module `modname` and `package.loaded[modname]` is not false, `require` simply returns the value stored there.

This variable is only a reference to the real table; assignments to this variable do not change the table used by `require`.

---

#### `package.loadlib (libname, funcname)`

Dynamically links the host program with the C library `libname`.

If `funcname` is `"*"`, then it only links with the library, making the symbols exported by the library available to other dynamically linked libraries. Otherwise, it looks for a function `funcname` inside the library and returns this function as a C function. (So, `funcname` must follow the prototype `lua_CFunction`).

This is a low-level function. It completely bypasses the package and module system. Unlike `require`, it does not perform any path searching and does not automatically add extensions. `libname` must be the complete file name of the C library, including if necessary a path and an extension. `funcname` must be the exact name exported by the C library (which may depend on the C compiler and linker used).

This function is not supported by Standard C. As such, it is only available on some platforms (Windows, Linux, Mac OS X, Solaris, BSD, plus other Unix systems that support the `dlfcn` standard).

---

#### `package.path`

The path used by `require` to search for a Lua loader.

At start-up, Lua initializes this variable with the value of the environment variable `LUA_PATH_5_2` or the environment variable `LUA_PATH` or with a default path defined in `luaconf.h`, if those environment variables are not defined. Any `;;` in the value of the environment variable is replaced by the default path.

---

#### `package.preload`

A table to store loaders for specific modules (see `require`).

This variable is only a reference to the real table; assignments to this variable do not change the table used by `require`.

---

#### `package.searchers`

A table used by `require` to control how to load modules.

Each entry in this table is a *searcher function*. When looking for a module, `require` calls each of these searchers in ascending order, with the module name (the argument given to `require`) as its sole parameter. The function can return another function (the module *loader*) plus an extra value that will be passed to that loader, or a string explaining why it did not find that module (or `nil` if it has nothing to say).

Lua initializes this table with four searcher functions.

The first searcher simply looks for a loader in the `package.preload` table.

The second searcher looks for a loader as a Lua library, using the path stored at `package.path`. The search is done as described in function `package.searchpath`.

The third searcher looks for a loader as a C library, using the path given by the variable `package.cpath`. Again, the search is done as described in function `package.searchpath`. For instance, if the C path is the string

```
"/usr/local/?.so;/usr/local/?.dll;/usr/local/?.init.so"
```

the searcher for module `foo` will try to open the files `./foo.so`, `./foo.dll`, and `/usr/local/foo/init.so`, in that order. Once it finds a C library, this searcher first uses a dynamic link facility to link the application with the library. Then it tries to find a C function inside the library to be used as the loader. The name of this C function is the string `"luaopen_"` concatenated with a copy of the module name where each dot is replaced by an underscore. Moreover, if the module name has a hyphen, its prefix up to (and including) the first hyphen is removed. For instance, if the module name is `a.v1-b.c`, the function name will be `luaopen_b_c`.

The fourth searcher tries an *all-in-one loader*. It searches the C path for a library for the root name of the given module. For instance, when requiring `a.b.c`,

it will search for a C library for **a**. If found, it looks into it for an open function for the submodule; in our example, that would be `luaopen_a_b_c`. With this facility, a package can pack several C submodules into one single library, with each submodule keeping its original open function.

All searchers except the first one (preload) return as the extra value the file name where the module was found, as returned by `package.searchpath`. The first searcher returns no extra value.

---

**package.searchpath** (name,path[,sep[,rep]])

Searches for the given **name** in the given **path**.

A **path** is a string containing a sequence of *templates* separated by semicolons. For each template, the function replaces each interrogation mark (if any) in the template with a copy of **name** wherein all occurrences of **sep** (a dot, by default) were replaced by **rep** (the system's directory separator, by default), and then tries to open the resulting file name.

For instance, if the path is the string

```
"./?.lua;./?.lc;/usr/local/?.init.lua"
```

the search for the name `foo.a` will try to open the files `./foo/a.lua`, `./foo/a.lc`, and `/usr/local/foo/a/init.lua`, in that order.

Returns the resulting name of the first file that it can open in read mode (after closing the file), or `nil` plus an error message if none succeeds. (This error message lists all file names it tried to open.)

## 6.4 · String Manipulation

This library provides generic functions for string manipulation, such as finding and extracting substrings, and pattern matching. When indexing a string in Lua, the first character is at position 1 (not at 0, as in C). Indices are allowed to be negative and are interpreted as indexing backwards, from the end of the string. Thus, the last character is at position -1, and so on.

The string library provides all its functions inside the table **string**. It also sets a metatable for strings where the `__index` field points to the **string** table. Therefore, you can use the string functions in object-oriented style. For instance, `string.byte(s,i)` can be written as `s:byte(i)`.

The string library assumes one-byte character encodings.

---

**string.byte** (s [, i [, j]])

Returns the internal numerical codes of the characters `s[i]`, `s[i+1]`, ..., `s[j]`. The default value for **i** is 1; the default value for **j** is **i**. These indices are corrected following the same rules of function **string.sub**.

Numerical codes are not necessarily portable across platforms.

---

**string.char** (...)

Receives zero or more integers. Returns a string with length equal to the number of arguments, in which each

character has the internal numerical code equal to its corresponding argument.

Numerical codes are not necessarily portable across platforms.

---

**string.dump** (function)

Returns a string containing a binary representation of the given function, so that a later **load** on this string returns a copy of the function (but with new upvalues).

---

**string.find** (s, pattern [, init [, plain]])

Looks for the first match of **pattern** in the string **s**. If it finds a match, then **find** returns the indices of **s** where this occurrence starts and ends; otherwise, it returns `nil`. A third, optional numerical argument **init** specifies where to start the search; its default value is 1 and can be negative. A value of `true` as a fourth, optional argument **plain** turns off the pattern matching facilities, so the function does a plain "find substring" operation, with no characters in **pattern** being considered magic. Note that if **plain** is given, then **init** must be given as well.

If the pattern has captures, then in a successful match the captured values are also returned, after the two indices.

---

**string.format** (formatstring, ...)

Returns a formatted version of its variable number of arguments following the description given in its first argument (which must be a string). The format string follows the same rules as the C function `sprintf`. The only differences are that the options/modifiers `*`, `h`, `L`, `l`, `n`, and `p` are not supported and that there is an extra option, `q`. The `q` option formats a string between double quotes, using escape sequences when necessary to ensure that it can safely be read back by the Lua interpreter. For instance, the call

```
string.format('%q', 'a string with "quotes" \nand \n new line')
```

may produce the string:

```
"a string with \"quotes\" and \n new line"
```

Options **A** and **a** (when available), **E**, **e**, **f**, **G**, and **g** all expect a number as argument. Options **c**, **d**, **i**, **o**, **u**, **X**, and **x** also expect a number, but the range of that number may be limited by the underlying C implementation. For options **o**, **u**, **X**, and **x**, the number cannot be negative. Option **q** expects a string; option **s** expects a string without embedded zeros. If the argument to option **s** is not a string, it is converted to one following the same rules of **tostring**.

---

**string.gmatch** (s, pattern)

Returns an iterator function that, each time it is called, returns the next captures from **pattern** over the string **s**. If **pattern** specifies no captures, then the whole match is produced in each call.

As an example, the following loop will iterate over all the words from string `s`, printing one per line:

```
s = "hello world from Lua"
for w in string.gmatch(s, "%a+") do
    print(w)
end
```

The next example collects all pairs `key=value` from the given string into a table:

```
t = {}
s = "from=world, to=Lua"
for k, v in string.gmatch(s, "(%w+)=(%w+)") do
    t[k] = v
end
```

For this function, a caret `^` at the start of a pattern does not work as an anchor, as this would prevent the iteration.

---

**string.gsub (s, pattern, repl [, n])**

Returns a copy of `s` in which all (or the first `n`, if given) occurrences of the `pattern` have been replaced by a replacement string specified by `repl`, which can be a string, a table, or a function. `gsub` also returns, as its second value, the total number of matches that occurred. The name `gsub` comes from *Global SUBstitution*.

If `repl` is a string, then its value is used for replacement. The character `%` works as an escape character: any sequence in `repl` of the form `%d`, with `d` between 1 and 9, stands for the value of the `d`-th captured substring. The sequence `%0` stands for the whole match. The sequence `%%` stands for a single `%`.

If `repl` is a table, then the table is queried for every match, using the first capture as the key.

If `repl` is a function, then this function is called every time a match occurs, with all captured substrings passed as arguments, in order.

In any case, if the pattern specifies no captures, then it behaves as if the whole pattern was inside a capture.

If the value returned by the table query or by the function call is a string or a number, then it is used as the replacement string; otherwise, if it is `false` or `nil`, then there is no replacement (that is, the original match is kept in the string).

Here are some examples:

```
x = string.gsub("hello world", "(%w+)", "%1 %1")
--> x="hello hello world world"
```

```
x = string.gsub("hello world", "%w+", "%0 %0", 1)
--> x="hello hello world"
```

```
x = string.gsub("hello world from Lua",
    "(%w+)%s*(%w+)", "%2 %1")
--> x="world hello Lua from"
```

```
x = string.gsub("home = $HOME, user = $USER",
    "%$(%w+)", os.getenv)
--> x="home = /home/roberto, user = roberto"
```

```
x = string.gsub("4+5 = $return 4+5$",
```

```
"%$(.-%)$",
function (s) return load(s]()
end)
--> x="4+5 = 9"

local t = {name="lua", version="5.2"}
x = string.gsub("$name-$version.tar.gz",
    "%$(%w+)", t)
--> x="lua-5.2.tar.gz"
```

---

**string.len (s)**

Receives a string and returns its length. The empty string `""` has length 0. Embedded zeros are counted, so `"a\000bc\000"` has length 5.

---

**string.lower (s)**

Receives a string and returns a copy of this string with all uppercase letters changed to lowercase. All other characters are left unchanged. The definition of what an uppercase letter is depends on the current locale.

---

**string.match (s, pattern [, init])**

Looks for the first *match* of `pattern` in the string `s`. If it finds one, then `match` returns the captures from the pattern; otherwise it returns `nil`. If `pattern` specifies no captures, then the whole match is returned. A third, optional numerical argument `init` specifies where to start the search; its default value is 1 and can be negative.

---

**string.rep (s, n [, sep])**

Returns a string that is the concatenation of `n` copies of the string `s` separated by the string `sep`. The default value for `sep` is the empty string (that is, no separator).

---

**string.reverse (s)**

Returns a string that is the string `s` reversed.

---

**string.sub (s, i [, j])**

Returns the substring of `s` that starts at `i` and continues until `j`; `i` and `j` can be negative. If `j` is absent, then it is assumed to be `-1` (which is the same as the string length). In particular, the call `string.sub(s, 1, j)` returns a prefix of `s` with length `j`, and `string.sub(s, -i)` returns a suffix of `s` with length `i`.

If, after the translation of negative indices, `i` is less than 1, it is corrected to 1. If `j` is greater than the string length, it is corrected to that length. If, after these corrections, `i` is greater than `j`, the function returns the empty string.

---

**string.upper (s)**

Receives a string and returns a copy of this string with all lowercase letters changed to uppercase. All other characters are left unchanged. The definition of what a lowercase letter is depends on the current locale.

## 6.4.1 · Patterns

### Character Class:

A *character class* is used to represent a set of characters. The following combinations are allowed in describing a character class:

- *x*: (where *x* is not one of the *magic characters* `~$()%. []*+-?`) represents the character *x* itself.
- `.` (a dot) represents all characters.
- `%a`: represents all letters.
- `%c`: represents all control characters.
- `%d`: represents all digits.
- `%g`: represents all printable characters except space.
- `%l`: represents all lowercase letters.
- `%p`: represents all punctuation characters.
- `%s`: represents all space characters.
- `%u`: represents all uppercase letters.
- `%w`: represents all alphanumeric characters.
- `%x`: represents all hexadecimal digits.
- `%x`: (where *x* is any non-alphanumeric character) represents the character *x*. This is the standard way to escape the magic characters. Any punctuation character (even the non magic) can be preceded by a `%` when used to represent itself in a pattern.
- `[set]`: represents the class which is the union of all characters in *set*. A range of characters can be specified by separating the end characters of the range, in ascending order, with a `-`. All classes `%x` described above can also be used as components in *set*. All other characters in *set* represent themselves. For example, `[%w_]` (or `[_%w]`) represents all alphanumeric characters plus the underscore, `[0-7]` represents the octal digits, and `[0-7%l%-]` represents the octal digits plus the lowercase letters plus the `-` character.  
The interaction between ranges and classes is not defined. Therefore, patterns like `[%a-z]` or `[a-%%]` have no meaning.
- `[^set]`: represents the complement of *set*, where *set* is interpreted as above.

For all classes represented by single letters (`%a`, `%c`, etc.), the corresponding uppercase letter represents the complement of the class. For instance, `%S` represents all non-space characters.

The definitions of letter, space, and other character groups depend on the current locale. In particular, the class `[a-z]` may not be equivalent to `%l`.

### Pattern Item:

A *pattern item* can be:

- a single character class, which matches any single character in the class;
- a single character class followed by `*`, which matches 0 or more repetitions of characters in the class. These repetition items will always match the longest possible sequence;
- a single character class followed by `+`, which matches 1 or more repetitions of characters in the class. These repetition items will always match the longest possible sequence;

- a single character class followed by `-`, which also matches 0 or more repetitions of characters in the class. Unlike `'*'`, these repetition items will always match the shortest possible sequence;
- a single character class followed by `?`, which matches 0 or 1 occurrence of a character in the class;
- `%n`, for *n* between 1 and 9; such item matches a substring equal to the *n*-th captured string (see below);
- `%bxy`, where *x* and *y* are two distinct characters; such item matches strings that start with *x*, end with *y*, and where the *x* and *y* are *balanced*. This means that, if one reads the string from left to right, counting +1 for an *x* and -1 for a *y*, the ending *y* is the first *y* where the count reaches 0. For instance, the item `%b()` matches expressions with balanced parentheses.
- `%f[set]`, a *frontier pattern*; such item matches an empty string at any position such that the next character belongs to *set* and the previous character does not belong to *set*. The set *set* is interpreted as previously described. The beginning and the end of the subject are handled as if they were the character `'\0'`.

### Pattern:

A *pattern* is a sequence of pattern items. A caret `^` at the beginning of a pattern anchors the match at the beginning of the subject string. A `$` at the end of a pattern anchors the match at the end of the subject string. At other positions, `^` and `$` have no special meaning and represent themselves.

### Captures:

A pattern can contain sub-patterns enclosed in parentheses; they describe *captures*. When a match succeeds, the substrings of the subject string that match captures are stored (*captured*) for future use. Captures are numbered according to their left parentheses. For instance, in the pattern `"(a*(.)%w(%s*))"`, the part of the string matching `"a*(.)%w(%s*)"` is stored as the first capture (and therefore has number 1); the character matching `"."` is captured with number 2, and the part matching `"%s*"` has number 3.

As a special case, the empty capture `()` captures the current string position (a number). For instance, if we apply the pattern `"()aa()"` on the string `"flaaap"`, there will be two captures: 3 and 5.

## 6.5 · Table Manipulation

This library provides generic functions for table manipulation. It provides all its functions inside the table `table`.

Remember that, whenever an operation needs the length of a table, the table should be a proper sequence or have a `__len` metamethod (see §3.4.6). All functions ignore non-numeric keys in tables given as arguments.

For performance reasons, all table accesses (`get/set`) performed by these functions are raw.

---

```
table.concat (list [, sep [, i [, j]])
```

Given a list where all elements are strings or numbers,



returns `list[i]..sep..list[i+1] ... sep..list[j]`. The default value for `sep` is the empty string, the default for `i` is 1, and the default for `j` is `#list`. If `i` is greater than `j`, returns the empty string.

---

`table.insert (list, [pos,] value)`

Inserts element `value` at position `pos` in `list`, shifting up the elements `list[pos]`, `list[pos+1]`, ..., `list[#list]`. The default value for `pos` is `#list+1`, so that a call `table.insert(t,x)` inserts `x` at the end of list `t`.

---

`table.pack (...)`

Returns a new table with all parameters stored into keys 1, 2, etc. and with a field `"n"` with the total number of parameters. Note that the resulting table may not be a sequence.

---

`table.remove (list [, pos])`

Removes from `list` the element at position `pos`, shifting down the elements `list[pos+1]`, `list[pos+2]`, ..., `list[#list]` and erasing element `list[#list]`. Returns the value of the removed element. The default value for `pos` is `#list`, so that a call `table.remove(t)` removes the last element of list `t`.

---

`table.sort (list [, comp])`

Sorts list elements in a given order, *in-place*, from `list[1]` to `list[#list]`. If `comp` is given, then it must be a function that receives two list elements and returns true when the first element must come before the second in the final order (so that `not comp(list[i+1],list[i])` will be true after the sort). If `comp` is not given, then the standard Lua operator `<` is used instead.

The sort algorithm is not stable; that is, elements considered equal by the given order may have their relative positions changed by the sort.

---

`table.unpack (list [, i [, j]])`

Returns the elements from the given table. This function is equivalent to

```
return list[i], list[i+1], ..., list[j]
```

By default, `i` is 1 and `j` is `#list`.

---

## 6.6 · Mathematical Functions

This library is an interface to the standard C math library. It provides all its functions inside the table `math`.

---

`math.abs (x)`

Returns the absolute value of `x`.

---

`math.acos (x)`

Returns the arc cosine of `x` (in radians).

---

`math.asin (x)`

Returns the arc sine of `x` (in radians).

---

`math.atan (x)`

Returns the arc tangent of `x` (in radians).

---

`math.atan2 (y, x)`

Returns the arc tangent of `y/x` (in radians), but uses the signs of both parameters to find the quadrant of the result. (It also handles correctly the case of `x` being zero.)

---

`math.ceil (x)`

Returns the smallest integer larger than or equal to `x`.

---

`math.cos (x)`

Returns the cosine of `x` (assumed to be in radians).

---

`math.cosh (x)`

Returns the hyperbolic cosine of `x`.

---

`math.deg (x)`

Returns the angle `x` (given in radians) in degrees.

---

`math.exp (x)`

Returns the value  $e^x$ .

---

`math.floor (x)`

Returns the largest integer smaller than or equal to `x`.

---

`math.fmod(x,y)`

Returns the remainder of the division of `x` by `y` that rounds the quotient towards zero.

---

`math.frexp(x)`

Returns `m` and `e` such that  $x = m2^e$ , `e` is an integer and the absolute value of `m` is in the range  $[0.5, 1)$  (or zero when `x` is zero).

---

`math.huge`

The value `HUGE_VAL`, a value larger than or equal to any other numerical value.

---

`math.ldexp(m,e)`

Returns  $m^e$  (`e` should be an integer).

---

`math.log(x[,base])`

Returns the logarithm of  $x$  in the given base. The default for `base` is  $e$  (so that the function returns the natural logarithm of  $x$ ).

---

`math.max(x,...)`

Returns the maximum value among its arguments.

---

`math.min(x,...)`

Returns the minimum value among its arguments.

---

`math.modf(x)`

Returns two numbers, the integral part of  $x$  and the fractional part of  $x$ .

---

`math.pi`

The value of  $\pi$ .

---

`math.pow(x,y)`

Returns  $x^y$ . (You can also use the expression  $x^y$  to compute this value.)

---

`math.rad(x)`

Returns the angle  $x$  (given in degrees) in radians.

---

`math.random([m[,n]])`

This function is an interface to the simple pseudo-random generator function `rand` provided by Standard C. (No guarantees can be given for its statistical properties.)

When called without arguments, returns a uniform pseudo-random real number in the range  $[0,1)$ . When called with an integer number  $m$ , `math.random` returns a uniform pseudo-random integer in the range  $[1,m]$ . When called with two integer numbers  $m$  and  $n$ , `math.random` returns a uniform pseudo-random integer in the range  $[m,n]$ .

---

`math.randomseed(x)`

Sets  $x$  as the "seed" for the pseudo-random generator: equal seeds produce equal sequences of numbers.

---

`math.sin(x)`

Returns the sine of  $x$  (assumed to be in radians).

---

`math.sinh(x)`

Returns the hyperbolic sine of  $x$ .

---

`math.sqrt(x)`

Returns the square root of  $x$ . (You can also use the expression  $x^{0.5}$  to compute this value.)

---

`math.tan(x)`

Returns the tangent of  $x$  (assumed to be in radians).

---

`math.tanh(x)`

Returns the hyperbolic tangent of  $x$ .

## 6.7 · Bitwise Operations

~~This library provides bitwise operations. It provides all its functions inside the table `bit32`.~~

~~Unless otherwise stated, all functions accept numeric arguments in the range  $(-2^{51}, +2^{51})$ ; each argument is normalized to the remainder of its division by  $2^{32}$  and truncated to an integer (in some unspecified way), so that its final value falls in the range  $[0, 2^{32} - 1]$ . Similarly, all results are in the range  $[0, 2^{32} - 1]$ . Note that `bit32.bnot(0)` is `0xFFFFFFFF`, which is different from `-1`.~~

---

~~`bit32.arshift(x, disp)`~~

~~Returns the number  $x$  shifted  $disp$  bits to the right. The number  $disp$  may be any representable integer. Negative displacements shift to the left.~~

~~This shift operation is what is called arithmetic shift. Vacant bits on the left are filled with copies of the higher bit of  $x$ ; vacant bits on the right are filled with zeros. In particular, displacements with absolute values higher than 31 result in zero or `0xFFFFFFFF` (all original bits are shifted out).~~

---

~~`bit32.band(...)`~~

~~Returns the bitwise *and* of its operands.~~

---

~~`bit32.bnot(x)`~~

~~Returns the bitwise negation of  $x$ . For any integer  $x$ , the following identity holds:~~

~~`assert(bit32.bnot(x) == (-1 - x) % 2^32)`~~

---

~~`bit32.bor(...)`~~

~~Returns the bitwise *or* of its operands.~~

---

~~`bit32.btest(...)`~~

~~Returns a boolean signaling whether the bitwise *and* of its operands is different from zero.~~

---

~~`bit32.bxor(...)`~~

~~Returns the bitwise *exclusive or* of its operands.~~

---

~~`bit32.extract(n,field[,width])`~~

~~Returns the unsigned number formed by the bits `field` to `field+width-1` from  $n$ . Bits are numbered from 0 (least significant) to 31 (most significant). All accessed bits must be in the range  $[0,31]$ .~~

~~The default for `width` is 1.~~

`bit32.replace (n, v, field [, width])`

Returns a copy of `n` with the bits `field` to `field + width - 1` replaced by the value `v`. See `bit32.extract` for details about `field` and `width`.

---

`bit32.lrotate (x, disp)`

Returns the number `x` rotated `disp` bits to the left. The number `disp` may be any representable integer.

For any valid displacement, the following identity holds:

```
assert(bit32.lrotate(x, disp) ==
       bit32.lrotate(x, disp % 32))
```

In particular, negative displacements rotate to the right.

---

`bit32.lshift (x, disp)`

Returns the number `x` shifted `disp` bits to the left. The number `disp` may be any representable integer. Negative displacements shift to the right. In any direction, vacant bits are filled with zeros. In particular, displacements with absolute values higher than 31 result in zero (all bits are shifted out).

For positive displacements, the following equality holds:

```
assert(bit32.lshift(b, disp) ==
       (b * 2^disp) % 2^32)
```

---

`bit32.rrotate (x, disp)`

Returns the number `x` rotated `disp` bits to the right. The number `disp` may be any representable integer.

For any valid displacement, the following identity holds:

```
assert(bit32.rrotate(x, disp) ==
       bit32.rrotate(x, disp % 32))
```

In particular, negative displacements rotate to the left.

---

`bit32.rshift (x, disp)`

Returns the number `x` shifted `disp` bits to the right. The number `disp` may be any representable integer. Negative displacements shift to the left. In any direction, vacant bits are filled with zeros. In particular, displacements with absolute values higher than 31 result in zero (all bits are shifted out).

For positive displacements, the following equality holds:

```
assert(bit32.rshift(b, disp) ==
       math.floor(b % 2^32 / 2^disp))
```

This shift operation is what is called logical shift.

## 6.8 · Input and Output Facilities

The I/O library provides two different styles for file manipulation. The first one uses implicit file descriptors; that is, there are operations to set a default input file and a default output file, and all input/output operations are over these default files. The second style uses explicit file descriptors.

When using implicit file descriptors, all operations are supplied by table `io`. When using explicit file descriptors, the operation `io.open` returns a file descriptor and then all operations are supplied as methods of the file descriptor.

The table `io` also provides three predefined file descriptors with their usual meanings from C: `io.stdin`, `io.stdout`, and `io.stderr`. The I/O library never closes these files.

Unless otherwise stated, all I/O functions return `nil` on failure (plus an error message as a second result and a system-dependent error code as a third result) and some value different from `nil` on success.

---

`io.close ([file])`

Equivalent to `file:close()`. Without a `file`, closes the default output file.

---

`io.flush ()`

Equivalent to `io.output():flush()`.

---

`io.input ([file])`

When called with a file name, it opens the named file (in text mode), and sets its handle as the default input file. When called with a file handle, it simply sets this file handle as the default input file. When called without parameters, it returns the current default input file.

In case of errors this function raises the error, instead of returning an error code.

---

`io.lines ([filename ...])`

Opens the given file name in read mode and returns an iterator function that works like `file:lines(...)` over the opened file. When the iterator function detects the end of file, it returns `nil` (to finish the loop) and automatically closes the file.

The call `io.lines()` (with no file name) is equivalent to `io.input():lines()`; that is, it iterates over the lines of the default input file. In this case it does not close the file when the loop ends.

In case of errors this function raises the error, instead of returning an error code.

---

`io.open (filename [, mode])`

This function opens a file, in the mode specified in the string `mode`. It returns a new file handle, or, in case of errors, `nil` plus an error message.

The `mode` string can be any of the following:

- `"r"`: read mode (the default);
- `"w"`: write mode;

- "a": append mode;
- "r+": update mode, all previous data is preserved;
- "w+": update mode, all previous data is erased;
- "a+": append update mode, previous data is preserved, writing is only allowed at the end of file.

The `mode` string can also have a `b` at the end, which is needed in some systems to open the file in binary mode.

---

`io.output ([file])`

Similar to `io.input`, but operates over the default output file.

---

`io.popen (prog [, mode])`

This function is system dependent and is not available on all platforms.

Starts program `prog` in a separated process and returns a file handle that you can use to read data from this program (if `mode` is "r", the default) or to write data to this program (if `mode` is "w").

---

`io.read (...)`

Equivalent to `io.input():read(...)`.

---

`io.tmpfile ()`

Returns a handle for a temporary file. This file is opened in update mode and it is automatically removed when the program ends.

---

`io.type (obj)`

Checks whether `obj` is a valid file handle. Returns the string "file" if `obj` is an open file handle, "closed file" if `obj` is a closed file handle, or `nil` if `obj` is not a file handle.

---

`io.write (...)`

Equivalent to `io.output():write(...)`.

---

`file:close ()`

Closes `file`. Note that files are automatically closed when their handles are garbage collected, but that takes an unpredictable amount of time to happen.

When closing a file handle created with `io.popen`, `file:close` returns the same values returned by `os.execute`.

---

`file:flush ()`

Saves any written data to `file`.

---

`file:lines (...)`

Returns an iterator function that, each time it is called, reads the file according to the given formats. When no format is given, uses "\*" as a default. As an example, the construction

`for c in file:lines(1) do body end`

will iterate over all characters of the file, starting at the current position. Unlike `io.lines`, this function does not close the file when the loop ends.

In case of errors this function raises the error, instead of returning an error code.

---

`file:read (...)`

Reads the file `file`, according to the given formats, which specify what to read. For each format, the function returns a string (or a number) with the characters read, or `nil` if it cannot read data with the specified format. When called without formats, it uses a default format that reads the next line (see below).

The available formats are

- "\*n": reads a number; this is the only format that returns a number instead of a string.
- "\*a": reads the whole file, starting at the current position. On end of file, it returns the empty string.
- "\*l": reads the next line skipping the end of line, returning `nil` on end of file. This is the default format.
- "\*L": reads the next line keeping the end of line (if present), returning `nil` on end of file.
- *number*: reads a string with up to this number of bytes, returning `nil` on end of file. If *number* is zero, it reads nothing and returns an empty string, or `nil` on end of file.

---

`file:seek ([whence [, offset]])`

Sets and gets the file position, measured from the beginning of the file, to the position given by `offset` plus a base specified by the string `whence`, as follows:

- "set": base is position 0 (beginning of the file);
- "cur": base is current position;
- "end": base is end of file;

In case of success, `seek` returns the final file position, measured in bytes from the beginning of the file. If `seek` fails, it returns `nil`, plus a string describing the error.

The default value for `whence` is "cur", and for `offset` is 0. Therefore, the call `file:seek()` returns the current file position, without changing it; the call `file:seek("set")` sets the position to the beginning of the file (and returns 0); and the call `file:seek("end")` sets the position to the end of the file, and returns its size.

---

`file:setvbuf (mode [, size])`

Sets the buffering mode for an output file. There are three available modes:

- "no": no buffering; the result of any output operation appears immediately.
- "full": full buffering; output operation is performed only when the buffer is full or when you explicitly `flush` the file (see `io.flush`).
- "line": line buffering; output is buffered until a newline is output or there is any input from some special files (such as a terminal device).

For the last two cases, `size` specifies the size of the buffer, in bytes. The default is an appropriate size.

---

`file:write (...)`

Writes the value of each of its arguments to `file`. The arguments must be strings or numbers.

In case of success, this function returns `file`. Otherwise it returns `nil` plus a string describing the error.

## 6.9 · Operating System Facilities

This library is implemented through table `os`.

---

`os.clock ()`

Returns an approximation of the amount in seconds of CPU time used by the program.

---

`os.date ([format [, time]])`

Returns a string or a table containing date and time, formatted according to the given string `format`.

If the `time` argument is present, this is the time to be formatted (see the `os.time` function for a description of this value). Otherwise, `date` formats the current time.

If `format` starts with `!`, then the date is formatted in Coordinated Universal Time. After this optional character, if `format` is the string `"*t"`, then `date` returns a table with the following fields: `year` (four digits), `month` (1–12), `day` (1–31), `hour` (0–23), `min` (0–59), `sec` (0–61), `wday` (weekday, Sunday is 1), `yday` (day of the year), and `isdst` (daylight saving flag, a boolean). This last field may be absent if the information is not available.

If `format` is not `"*t"`, then `date` returns the date as a string, formatted according to the same rules as the C function `strftime`.

When called without arguments, `date` returns a reasonable date and time representation that depends on the host system and on the current locale (that is, `os.date()` is equivalent to `os.date("%c")`).

On some systems, this function may be not thread safe.

---

`os.difftime (t2, t1)`

Returns the number of seconds from time `t1` to time `t2`. In POSIX, Windows, and some other systems, this value is exactly `t2-t1`.

---

`os.execute ([command])`

This function is equivalent to the C function `system`. It passes `command` to be executed by an operating system shell. Its first result is `true` if the command terminated successfully, or `nil` otherwise. After this first result the function returns a string and a number, as follows:

- `"exit"`: the command terminated normally; the following number is the exit status of the command.
- `"signal"`: the command was terminated by a signal; the following number is the signal that terminated the command.

When called without a `command`, `os.execute` returns a boolean that is true if a shell is available.

---

`os.exit ([code [, close]])`

Calls the C function `exit` to terminate the host program. If `code` is `true`, the returned status is `EXIT_SUCCESS`; if `code` is `false`, the returned status is `EXIT_FAILURE`; if `code` is a number, the returned status is this number. The default value for `code` is `true`.

If the optional second argument `close` is true, closes the Lua state before exiting.

---

`os.getenv (varname)`

Returns the value of the process environment variable `varname`, or `nil` if the variable is not defined.

---

`os.remove (filename)`

Deletes the file (or empty directory, on POSIX systems) with the given name. If this function fails, it returns `nil`, plus a string describing the error and the error code.

---

`os.rename (oldname, newname)`

Renames file or directory named `oldname` to `newname`. If this function fails, it returns `nil`, plus a string describing the error and the error code.

---

`os.setlocale (locale [, category])`

Sets the current locale of the program. `locale` is a system-dependent string specifying a locale; `category` is an optional string describing which category to change: `"all"`, `"collate"`, `"ctype"`, `"monetary"`, `"numeric"`, or `"time"`; the default category is `"all"`. The function returns the name of the new locale, or `nil` if the request cannot be honored.

If `locale` is the empty string, the current locale is set to an implementation-defined native locale. If `locale` is the string `"C"`, the current locale is set to the standard C locale.

When called with `nil` as the first argument, this function only returns the name of the current locale for the given category.

---

`os.time ([table])`

Returns the current time when called without arguments, or a time representing the date and time specified by the given table. This table must have fields `year`, `month`, and `day`, and may have fields `hour` (default is 12), `min` (default is 0), `sec` (default is 0), and `isdst` (default is `nil`). For a description of these fields, see the `os.date` function.

The returned value is a number, whose meaning depends on your system. In POSIX, Windows, and some other systems, this number counts the number of seconds since some given start time (the "epoch"). In other systems, the meaning is not specified, and the number returned by `time` can be used only as an argument to `os.date` and `os.difftime`.

---

**os.tmpname ()**

Returns a string with a file name that can be used for a temporary file. The file must be explicitly opened before its use and explicitly removed when no longer needed.

On POSIX systems, this function also creates a file with that name, to avoid security risks. (Someone else might create the file with wrong permissions in the time between getting the name and creating the file.) You still have to open the file to use it and to remove it (even if you do not use it).

When possible, you may prefer to use **io.tmpfile**, which automatically removes the file when the program ends.

## 6.10 · The Debug Library

This library provides the functionality of the debug interface (§4.9) to Lua programs. You should exert care when using this library. Several of its functions violate basic assumptions about Lua code (e.g., that variables local to a function cannot be accessed from outside; that userdata metatables cannot be changed by Lua code; that Lua programs do not crash) and therefore can compromise otherwise secure code. Moreover, some functions in this library may be slow.

All functions in this library are provided inside the **debug** table. All functions that operate over a thread have an optional first argument which is the thread to operate over. The default is always the current thread.

---

**debug.debug ()**

Enters an interactive mode with the user, running each string that the user enters. Using simple commands and other debug facilities, the user can inspect global and local variables, change their values, evaluate expressions, and so on. A line containing only the word **cont** finishes this function, so that the caller continues its execution.

Note that commands for **debug.debug** are not lexically nested within any function and so have no direct access to local variables.

---

**debug.gethook ([thread])**

Returns the current hook settings of the thread, as three values: the current hook function, the current hook mask, and the current hook count (as set by the **debug.sethook** function).

---

**debug.getinfo ([thread,] f [, what])**

Returns a table with information about a function. You can give the function directly or you can give a number as the value of **f**, which means the function running at level **f** of the call stack of the given thread: level 0 is the current function (**getinfo** itself); level 1 is the function that called **getinfo** (except for tail calls, which do not count on the stack); and so on. If **f** is a number larger than the number of active functions, then **getinfo** returns **nil**.

The returned table can contain all the fields returned by **lua\_getinfo**, with the string **what** describing which fields to fill in. The default for **what** is to get all information available, except the table of valid lines. If present, the option **'f'** adds a field named **func** with the function itself. If present, the option **'L'** adds a field named **activelines** with the table of valid lines.

For instance, the expression **debug.getinfo(1,"n").name** returns a table with a name for the current function, if a reasonable name can be found, and the expression **debug.getinfo(print)** returns a table with all available information about the **print** function.

---

**debug.getlocal ([thread,] f, local)**

This function returns the name and the value of the local variable with index **local** of the function at level **f** of the stack. This function accesses not only explicit local variables, but also parameters, temporaries, etc.

The first parameter or local variable has index 1, and so on, until the last active variable. Negative indices refer to vararg parameters; -1 is the first vararg parameter. The function returns **nil** if there is no variable with the given index, and raises an error when called with a level out of range. (You can call **debug.getinfo** to check whether the level is valid.)

Variable names starting with **'C'** (open parentheses) represent internal variables (loop control variables, temporaries, varargs, and C function locals).

The parameter **f** may also be a function. In that case, **getlocal** returns only the name of function parameters.

---

**debug.getmetatable (value)**

Returns the metatable of the given **value** or **nil** if it does not have a metatable.

---

**debug.getregistry ()**

Returns the registry table (see §4.5).

---

**debug.getupvalue (f, up)**

This function returns the name and the value of the up-value with index **up** of the function **f**. The function returns **nil** if there is no upvalue with the given index.

---

**debug.getuservalue (u)**

Returns the Lua value associated to **u**. If **u** is not a userdata, returns **nil**.

---

**debug.sethook ([thread,] hook, mask [, count])**

Sets the given function as a hook. The string **mask** and the number **count** describe when the hook will be called. The string **mask** may have the following characters, with the given meaning:

- **c**: the hook is called every time Lua calls a function;
- **r**: the hook is called every time Lua returns from a function;

- 1: the hook is called every time Lua enters a new line of code.

With a `count` different from zero, the hook is called after every `count` instructions.

When called without arguments, `debug.sethook` turns off the hook.

When the hook is called, its first parameter is a string describing the event that has triggered its call: `"call"` (or `"tail call"`), `"return"`, `"line"`, and `"count"`. For line events, the hook also gets the new line number as its second parameter. Inside a hook, you can call `getinfo` with level 2 to get more information about the running function (level 0 is the `getinfo` function, and level 1 is the hook function).

---

`debug.setlocal ([thread,] level, local, value)`

This function assigns the value `value` to the local variable with index `local` of the function at level `level` of the stack. The function returns `nil` if there is no local variable with the given index, and raises an error when called with a `level` out of range. (You can call `getinfo` to check whether the level is valid.) Otherwise, it returns the name of the local variable.

See `debug.getlocal` for more information about variable indices and names.

---

`debug.setmetatable (value, table)`

Sets the metatable for the given `value` to the given `table` (which can be `nil`). Returns `value`.

---

`debug.setupvalue (f, up, value)`

This function assigns the value `value` to the upvalue with index `up` of the function `f`. The function returns `nil` if there is no upvalue with the given index. Otherwise, it returns the name of the upvalue.

---

`debug.setuservalue (udata, value)`

Sets the given `value` as the Lua value associated to the given `udata`. `value` must be a table or `nil`; `udata` must be a full userdata.

Returns `udata`.

---

`debug.traceback ([thread,] [message [,level]])`

If `message` is present but is neither a string nor `nil`, this function returns `message` without further processing. Otherwise, it returns a string with a traceback of the call stack. An optional `message` string is appended at the beginning of the traceback. An optional `level` number tells at which level to start the traceback (default is 1, the function calling `traceback`).

---

`debug.upvalueid (f, n)`

Returns an unique identifier (as a light userdata) for the upvalue numbered `n` from the given function.

These unique identifiers allow a program to check whether different closures share upvalues. Lua closures

that share an upvalue (that is, that access a same external local variable) will return identical ids for those upvalue indices.

---

`debug.upvaluejoin (f1, n1, f2, n2)`

Make the `n1`-th upvalue of the Lua closure `f1` refer to the `n2`-th upvalue of the Lua closure `f2`.

## 7 · Lua Standalone

Although Lua has been designed as an extension language, to be embedded in a host C program, it is also frequently used as a standalone language. An interpreter for Lua as a standalone language, called simply `lua`, is provided with the standard distribution. The standalone interpreter includes all standard libraries, including the `debug` library. Its usage is:

`lua [options] [script [args]]`

The options are:

- `-e stat`: executes string `stat`;
- `-l mod`: `'requires' mod`;
- `-i`: enters interactive mode after running a script;
- `-v`: prints version information;
- `-E`: ignores environment variables;
- `--`: stops handling options;
- `-:` executes `stdin` as a file and stops handling options.

After handling its options, `lua` runs the given script, passing to it the given `args` as string arguments. When called without arguments, `lua` behaves as `lua -v -i` when the standard input (`stdin`) is a terminal, and as `lua -` otherwise.

When called without option `-E`, the interpreter checks for an environment variable `LUA_INIT_5_2` (or `LUA_INIT` if it is not defined) before running any argument. If the variable content has the format `@filename`, then `lua` executes the file. Otherwise, `lua` executes the string itself.

When called with option `-E`, besides ignoring `LUA_INIT`, Lua also ignores the values of `LUA_PATH` and `LUA_CPATH`, setting the values of `package.path` and `package.cpath` with the default paths defined in `luaconf.h`.

All options are handled in order, except `-i` and `-E`. For instance, an invocation like

```
$ lua -e'a=1' -e 'print(a)' script.lua
```

will first set `a` to 1, then print the value of `a`, and finally run the file `script.lua` with no arguments. (Here `$` is the shell prompt. Your prompt may be different.)

Before starting to run the script, `lua` collects all arguments in the command line in a global table called `arg`. The script name is stored at index 0, the first argument after the script name goes to index 1, and so on. Any arguments before the script name (that is, the interpreter name plus the options) go to negative indices. For instance, in the call

```
$ lua -la b.lua t1 t2
```



the interpreter first runs the file `a.lua`, then creates a table

```
arg = { [-2] = "lua", [-1] = "-la",  
        [0] = "b.lua",  
        [1] = "t1", [2] = "t2" }
```

and finally runs the file `b.lua`. The script is called with `arg[1]`, `arg[2]`, ... as arguments; it can also access these arguments with the `vararg` expression ...

In interactive mode, if you write an incomplete statement, the interpreter waits for its completion by issuing a different prompt.

In case of unprotected errors in the script, the interpreter reports the error to the standard error stream. If the error object is a string, the interpreter adds a stack traceback to it. Otherwise, if the error object has a metamethod `__tostring`, the interpreter calls this metamethod to produce the final message. Finally, if the error object is `nil`, the interpreter does not report the error.

When finishing normally, the interpreter closes its main Lua state (see `lua_close`). The script can avoid this step by calling `os.exit` to terminate.

To allow the use of Lua as a script interpreter in Unix systems, the standalone interpreter skips the first line of a chunk if it starts with `#`. Therefore, Lua scripts can be made into executable programs by using `chmod +x` and the `#!` form, as in

```
#!/usr/local/bin/lua
```

(Of course, the location of the Lua interpreter may be different in your machine. If `lua` is in your `PATH`, then

```
#!/usr/bin/env lua
```

is a more portable solution.)

## ~~8 · Incompatibilities with the Previous Version~~

~~Here we list the incompatibilities that you may find when moving a program from Lua 5.1 to Lua 5.2. You can avoid some incompatibilities by compiling Lua with appropriate options (see file `luaconf.h`). However, all these compatibility options will be removed in the next version of Lua. Similarly, all features marked as deprecated in Lua 5.1 have been removed in Lua 5.2.~~

### ~~8.1 · Changes in the Language~~

- ~~o The concept of *environment* changed. Only Lua functions have environments. To set the environment of a Lua function, use the variable `_ENV` or the function `load`.~~
- ~~o Functions no longer have environments. Use an upvalue with a shared table if you need to keep shared state among several C functions. (You may use `luaL_setfuncs` to open a C library with all functions sharing a common upvalue.)~~
- ~~To manipulate the "environment" of a userdata (which is now called *user value*), use the new functions `lua_getuservalue` and `lua_setuservalue`.~~

- ~~o Lua identifiers cannot use locale-dependent letters.~~
- ~~o Doing a step or a full collection in the garbage collector does not restart the collector if it has been stopped.~~
- ~~o Weak tables with weak keys now perform like *ephemeron tables*.~~
- ~~o The event *tail return* in debug hooks was removed. Instead, tail calls generate a special new event, *tail call*, so that the debugger can know that there will not be a corresponding return event.~~
- ~~o Equality between function values has changed. Now, a function definition may not create a new value; it may reuse some previous value if there is no observable difference to the new function.~~

## ~~8.2 · Changes in the Libraries~~

- ~~o Function `module` is deprecated. It is easy to set up a module with regular Lua code. Modules are not expected to set global variables.~~
- ~~o Functions `setfenv` and `getfenv` were removed, because of the changes in environments.~~
- ~~o Function `math.log10` is deprecated. Use `math.log` with 10 as its second argument, instead.~~
- ~~o Function `loadstring` is deprecated. Use `load` instead; it now accepts string arguments and are exactly equivalent to `loadstring`.~~
- ~~o Function `table.maxn` is deprecated. Write it in Lua if you really need it.~~
- ~~o Function `os.execute` now returns `true` when command terminates successfully and `nil` plus error information otherwise.~~
- ~~o Function `unpack` was moved into the table library and therefore must be called as `table.unpack`.~~
- ~~o Character class `%z` in patterns is deprecated, as now patterns may contain `'\0'` as a regular character.~~
- ~~o The table `package.loaders` was renamed `package.searchers`.~~
- ~~o Lua does not have bytecode verification anymore. So, all functions that load code (`load` and `loadfile`) are potentially insecure when loading untrusted binary data. (Actually, those functions were already insecure because of flaws in the verification algorithm.) When in doubt, use the `mode` argument of those functions to restrict them to loading textual chunks.~~
- ~~o The standard paths in the official distribution may change between versions.~~

## ~~8.3 · Changes in the API~~

- ~~o Pseudoindex `LUA_GLOBALSINDEX` was removed. You must get the global environment from the registry (see §4.5).~~
- ~~o Pseudoindex `LUA_ENVIRONINDEX` and functions `lua_getfenv`/`lua_setfenv` were removed, as C functions no longer have environments.~~
- ~~o Function `luaL_register` is deprecated. Use `luaL_setfuncs` so that your module does not create globals. (Modules are not expected to set global variables anymore.)~~