

The Arena Library

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# Chapter 1

## C Basic Library: Arena Library

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0.2.1

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**Date:**

last modified on 2011-01-24

### 1.1 Introduction

This document specifies the Arena Library which belongs to the C Basic Library. The basic structure is from David Hanson's book, "C Interfaces and Implementations." I modified the original implementation to make it conform to the C standard and to enhance its readability; for example a prefix is used more strictly in order to avoid the user namespace pollution.

Since the book explains its design and implementation in a very comprehensive way, not to mention the copyright issues, it is nothing but waste to repeat it here, so I finish this document by giving a brief motivation and introduction to the library; how to use the facilities is deeply explained in files that define them.

`malloc()` and other related functions from `<stdlib.h>` provide facilities for the size-based memory allocation strategy. Each invocation to allocation functions requires a corresponding invocation to deallocation functions in order to avoid the memory leakage problem. Under certain circumstances the size-based memory allocator is not the best way to manage storage. For example, consider a script interpreter that accepts multiple scripts and parses them for execution in sequence. During running a script, many data structures including trees from a parser and tables for symbols should be maintained and those structures often require complicated patterns of memory allocation/deallocation. Besides, they should be correctly freed after the script has been processed and before processing of the next script starts off. In such a situation, a lifetime-

based memory allocator can work better and simplify the patterns of (de)allocation. With a lifetime-based memory allocator, all storages allocated for processing a script is remembered somehow, and all the instances can be freed at a time when processing the script has finished. The Arena Library provides a lifetime-based memory allocator. Hanson's book also mentions constructing a graphic user interface (having various features like input forms, scroll bars and buttons) as an example where a lifetime-based allocator does better than a size-based one.

The Arena Library reserves identifiers starting with `arena_` and `ARENA_`, and imports the Assertion Library and the Exception Handling Library. Even if it does not depend on the Memory Management Library, it also uses the identifier `MEM_MAXALIGN`.

## 1.2 How to Use The Library

Basically, using the Arena Library to allocate storages does not quite differ from using `malloc()` or similars from `<stdlib.h>`. The differences are that every allocation function takes an additional argument to specify an arena, and that there is no need to invoke a deallocation function for each of allocated storage blocks; a function to free all storages associated with an arena is provided.

```
typeA *p = malloc(sizeof(*p));
...
typeB *q = malloc(sizeof(*p));
...
free(p);
free(q);
```

For example, suppose that `p` and `q` point to two areas that have been allocated at different places but can be freed at the same time. As the number of such instances increases, deallocating them gets more complicated and thus necessarily more error-prone.

```
typeA *p = ARENA_ALLOC(myarena, sizeof(*p));
...
typeB *q = ARENA_ALLOC(myarena, sizeof(*q));
...
ARENA_FREE(myarena);
```

On the other hand, if the allocator the Arena Library offers is used, only one call to [ARENA\\_FREE\(\)](#) frees all storages associated with an arena, `myarena`.

Applying to the problem mentioned to introduce a lifetime-based allocator, all storages for data structures used while a script is processed can be associated with an arena and get freed readily by [ARENA\\_FREE\(\)](#) before moving to the next script.

As `<stdlib.h>` provides `malloc()` and `calloc()`, this library does [ARENA\\_ALLOC\(\)](#) and [ARENA\\_CALLOC\(\)](#) taking similar arguments. [ARENA\\_FREE\(\)](#) does what `free()` does (actually, it does more as explained above). [ARENA\\_NEW\(\)](#) creates an arena with which allocated storages are associated, and [ARENA\\_DISPOSE\(\)](#) destroys an arena, which means that an arena may be reused repeatedly even after all storages with it have been freed by [ARENA\\_FREE\(\)](#).

### 1.2.1 Some Caveats

As in the debugging version of the Memory Management Library, `MEM_MAXALIGN` indicates the common alignment factor; in other words, the alignment factor of pointers `malloc()` returns. If it is not given, the library tries to guess a proper value, but no guarantee that the guess is correct. Therefore, it is recommended to give a proper definition for `MEM_MAXALIGN` (via a compiler option like `-D`, if available).

Note that the Arena Library does not rely on the Memory Management Library. This means it constitutes a completely different allocator from the latter. Thus, the debugging version of the Memory Management Library cannot detect problems occurred in the storages maintained by the Arena Library.

## 1.3 Boilerplate Code

Using an arena starts with creating it:

```
arena_t myarena = ARENA_NEW();
```

As in the Memory Management Library, you don't need to check the return value of [ARENA\\_NEW\(\)](#); an exception named `arena_exceptFailNew` is raised if the creation fails (see the Exception Handling Library for how to handle exceptions). Creating an arena is different from allocating necessary storages. With an arena, you can freely allocate storages that belong to it with [ARENA\\_ALLOC\(\)](#) or [ARENA\\_CALLOC\(\)](#) as in:

```
sometype_t *p = ARENA_ALLOC(myarena, sizeof(*p));  
othertype_t *q = ARENA_CALLOC(myarena, 10, sizeof(*q));
```

Again, you don't have to check the return value of these invocations. If no storage is able to be allocated, an exception, `arena_exceptFailAlloc` is raised. Due to problems in implementation, adjusting the size of the allocated storage is not supported; there is no `ARENA_REALLOC()` or `ARENA_RESIZE()` that corresponds to `realloc()`.

There are two ways to release storages with an arena: [ARENA\\_FREE\(\)](#) and [ARENA\\_DISPOSE\(\)](#).

```
ARENA_FREE(myarena);  
... myarena can be reused ...  
ARENA_DISPOSE(myarena);
```

[ARENA\\_FREE\(\)](#) deallocates any storage belonging to an arena, while [ARENA\\_DISPOSE\(\)](#) does the same job and also destroy the arena to make it no more usable.

If you will use a tool like Valgrind to detect memory problems, see [arena\\_dispose\(\)](#); [ARENA\\_DISPOSE\(\)](#) is a simple macro wrapper for [arena\\_dispose\(\)](#) to keep the interface to the library consistent.

## 1.4 Future Directions

### 1.4.1 Minor Changes

To mimic the behavior of `calloc()` specified by the standard, it is required for `ARENA_CALLOC()` to successfully return a null pointer when it cannot allocate the storage of the requested size. Since this does not allow overflow, it has to carefully check overflow when calculating the total size.

## 1.5 Contact Me

Visit <http://project.woong.org> to get the latest version of this library. Only a small portion of my homepage (<http://www.woong.org>) is maintained in English, thus one who is not good at Korean would have difficulty when navigating most of other pages served in Korean. If you think the information you are looking for is on pages written in Korean you cannot read, do not hesitate to send me an email asking for help.

Any comments about the library are welcomed. If you have a proposal or question on the library just email me, and then I will reply as soon as possible.

## 1.6 Copyright

I do not wholly hold the copyright of this library; it is mostly held by David Hanson as stated in his book, "C: Interfaces and Implementations:"

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Copyright (C) 2009-2011 by Jun Woong.

This package is a lifetime-based memory allocator implementation by Jun Woong. The implementation was written so as to conform with the Standard C published by ISO 9899:1990 and ISO 9899:1999.

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## **Chapter 2**

### **Todo List**

**Global `arena_calloc`** Some improvements are possible and planned:

- the C standard requires `calloc()` return a null pointer if it cannot allocate storage of the size  $c * n$  in bytes, which allows no overflow in computing the multiplication. So overflow checking is necessary to mimic the behavior of `calloc()`.

# Chapter 3

## File Index

### 3.1 File List

Here is a list of all documented files with brief descriptions:

<a href="#">arena.c</a> (Source for Arena Library (CBL)) . . . . .	11
<a href="#">arena.h</a> (Header for Arena Library (CBL)) . . . . .	16



# Chapter 4

## File Documentation

### 4.1 arena.c File Reference

Source for Arena Library (CBL).

```
#include <stddef.h>
```

```
#include <stdlib.h>
```

```
#include <string.h>
```

```
#include "cbl/assert.h"
```

```
#include "cbl/except.h"
```

```
#include "arena.h"
```

Include dependency graph for arena.c:

#### Data Structures

- struct **arena\_t**
- union **align**
- union **header**

#### Defines

- #define **MULTIPLE**(x, y) (((x)+(y)-1)/(y)) \* (y)

- #define **ALIGNED**(p) ((uintptr\_t)(p) % sizeof(union align) == 0)
- #define **FREE\_THRESHOLD** 10

## Typedefs

- typedef unsigned long **uintptr\_t**

## Functions

- **arena\_t** \*() **arena\_new** (void)  
*creates a new arena.*
- void() **arena\_dispose** (**arena\_t** \*\*parena)  
*disposes an arena.*
- void \*() **arena\_alloc** (**arena\_t** \*arena, size\_t n, const char \*file, int line)  
*allocates storage associated with an arena.*
- void \*() **arena\_calloc** (**arena\_t** \*arena, size\_t c, size\_t n, const char \*file, int line)  
*allocates zero-filled storage associated with an arena.*
- void() **arena\_free** (**arena\_t** \*arena)  
*deallocates all storages belonging to an arena.*

## Variables

- const except\_t **arena\_exceptfailNew** = { "Arena creation failed" }  
*exception for arena creation failure.*
- const except\_t **arena\_exceptfailAlloc** = { "Arena allocation failed" }  
*exception for arena memory allocation failure.*

### 4.1.1 Detailed Description

Source for Arena Library (CBL).

### 4.1.2 Function Documentation

#### 4.1.2.1 void\*() **arena\_alloc** (**arena\_t** \* *arena*, size\_t *n*, const char \* *file*, int *line*)

allocates storage associated with an arena.

[arena\\_alloc\(\)](#) allocates storage for an arena as `malloc()` or `mem_alloc()` does.

Possible exceptions: `assert_exceptfail`, `arena_exceptfailAlloc`

Unchecked errors: foreign data structure given for `arena`

**Parameters:**

- ↔ *arena* arena for which storage to be allocated
- ← *n* size of storage requested
- ← *file* file name in which storage requested
- ← *func* function name in which storage requested (if C99 supported)
- ← *line* line number on which storage requested

**Returns:**

storage allocated for given arena

Here is the caller graph for this function:

**4.1.2.2 void\*() arena\_calloc (arena\_t \* arena, size\_t c, size\_t n, const char \* file, int line)**

allocates zero-filled storage associated with an arena.

[arena\\_calloc\(\)](#) does the same as [arena\\_alloc\(\)](#) except that it returns zero-filled storage.

Possible exceptions: `assert_exceptfail`, `arena_exceptfailAlloc`

Unchecked errors: foreign data structure given for `arena`

**Parameters:**

- ↔ *arena* arena for which zero-filled storage is to be allocated
- ← *c* number of items to be allocated
- ← *n* size in bytes for one item
- ← *file* file name in which storage requested
- ← *func* function name in which storage requested (if C99 supported)
- ← *line* line number on which storage requested

**Returns:**

zero-filled storage allocated for arena

**Todo**

Some improvements are possible and planned:

- the C standard requires `calloc()` return a null pointer if it cannot allocate storage of the size `c * n` in bytes, which allows no overflow in computing the multiplication. So overflow checking is necessary to mimic the behavior of `calloc()`.

Here is the call graph for this function:

#### 4.1.2.3 `void() arena_dispose (arena_t ** parena)`

disposes an arena.

`arena_dispose()` releases storages belonging to a given arena and disposes it. Do not confuse with `arena_free()` which gets all storages of an arena deallocated but does not destroy the arena itself.

Note that storages belonging to `freelist` is not deallocated by `arena_dispose()` because it is possibly used by other arenas. Thus, a tool detecting the memory leakage problem might say there is leakage caused by the library, but that is intended not a bug.

Possible exceptions: `assert_exceptfail`

Unchecked errors: foreign data structure given for `parena`

#### Parameters:

↔ *parena* pointer to arena to dispose

#### Returns:

nothing

Here is the call graph for this function:

#### 4.1.2.4 `void() arena_free (arena_t * arena)`

deallocates all storages belonging to an arena.

`arena_free()` releases all storages belonging to a given arena.

Possible exceptions: `assert_exceptfail`

Unchecked errors: foreign data structure given for `arena`

**Parameters:**

↔ *arena* arena whose storages to be deallocated

**Returns:**

nothing

Here is the caller graph for this function:

**4.1.2.5 arena\_t\*() arena\_new (void)**

creates a new arena.

[arena\\_new\(\)](#) creates a new arena and initialize it to indicate an empty arena.

Possible exceptions: arena\_exceptfailNew

Unchecked errors: none

**Returns:**

new arena created

## 4.2 arena.h File Reference

Header for Arena Library (CBL).

```
#include <stddef.h>
#include "cbl/except.h"
```

Include dependency graph for arena.h:

This graph shows which files directly or indirectly include this file:

### Defines

- #define [ARENA\\_NEW\(\)](#) (`arena_new()`)  
*allocates a new arena.*
- #define [ARENA\\_DISPOSE\(pa\)](#) (`arena_dispose(pa)`)  
*destroys an arena pointed to by pa.*
- #define [ARENA\\_ALLOC\(a, n\)](#) (`arena_alloc((a), (n), __FILE__, __LINE__)`)  
*allocates storage whose byte length is n for an arena a.*
- #define [ARENA\\_CALLOC\(a, c, n\)](#) (`arena_calloc((a), (c), (n), __FILE__, __LINE__)`)  
*allocates zero-filled storage of the size c \* n for an arena a.*
- #define [ARENA\\_FREE\(a\)](#) (`arena_free(a)`)  
*deallocates the storage belonging to an arena a.*

### Typedefs

- typedef struct [arena\\_t](#) `arena_t`

*represents an arena.*

## Functions

### arena creating functions:

- [arena\\_t \\* arena\\_new](#) (void)  
*creates a new arena.*

### memory allocating/deallocating functions:

- void \* [arena\\_alloc](#) (arena\_t \*, size\_t n, const char \*, int)  
*allocates storage associated with an arena.*
- void \* [arena\\_calloc](#) (arena\_t \*, size\_t c, size\_t n, const char \*, int)  
*allocates zero-filled storage associated with an arena.*
- void [arena\\_free](#) (arena\_t \*arena)  
*deallocates all storages belonging to an arena.*

### arena destroying functions:

- void [arena\\_dispose](#) (arena\_t \*\*)  
*disposes an arena.*

## Variables

- const except\_t [arena\\_exceptfailNew](#)  
*exception for arena creation failure.*
- const except\_t [arena\\_exceptfailAlloc](#)  
*exception for arena memory allocation failure.*

### 4.2.1 Detailed Description

Header for Arena Library (CBL).

Documentation for Arena Library (CBL).

## 4.2.2 Typedef Documentation

### 4.2.2.1 typedef struct arena\_t arena\_t

represents an arena.

`arena_t` represents an arena to which storages belongs.

## 4.2.3 Function Documentation

### 4.2.3.1 void\* arena\_alloc (arena\_t \* arena, size\_t n, const char \* file, int line)

allocates storage associated with an arena.

[arena\\_alloc\(\)](#) allocates storage for an arena as `malloc()` or `mem_alloc()` does.

Possible exceptions: `assert_exceptfail`, `arena_exceptfailAlloc`

Unchecked errors: foreign data structure given for `arena`

#### Parameters:

- ↔ *arena* arena for which storage to be allocated
- ← *n* size of storage requested
- ← *file* file name in which storage requested
- ← *func* function name in which storage requested (if C99 supported)
- ← *line* line number on which storage requested

#### Returns:

storage allocated for given arena

Here is the caller graph for this function:

### 4.2.3.2 void\* arena\_calloc (arena\_t \* arena, size\_t c, size\_t n, const char \* file, int line)

allocates zero-filled storage associated with an arena.

[arena\\_calloc\(\)](#) does the same as [arena\\_alloc\(\)](#) except that it returns zero-filled storage.

Possible exceptions: `assert_exceptfail`, `arena_exceptfailAlloc`

Unchecked errors: foreign data structure given for `arena`

#### Parameters:

- ↔ *arena* arena for which zero-filled storage is to be allocated

- ← *c* number of items to be allocated
- ← *n* size in bytes for one item
- ← *file* file name in which storage requested
- ← *func* function name in which storage requested (if C99 supported)
- ← *line* line number on which storage requested

**Returns:**

zero-filled storage allocated for arena

**Todo**

Some improvements are possible and planned:

- the C standard requires `calloc()` return a null pointer if it cannot allocate storage of the size  $c * n$  in bytes, which allows no overflow in computing the multiplication. So overflow checking is necessary to mimic the behavior of `calloc()`.

Here is the call graph for this function:

**4.2.3.3 void arena\_dispose (arena\_t \*\* *parena*)**

disposes an arena.

`arena_dispose()` releases storages belonging to a given arena and disposes it. Do not confuse with `arena_free()` which gets all storages of an arena deallocated but does not destroy the arena itself.

Note that storages belonging to `freelist` is not deallocated by `arena_dispose()` because it is possibly used by other arenas. Thus, a tool detecting the memory leakage problem might say there is leakage caused by the library, but that is intended not a bug.

Possible exceptions: `assert_exceptfail`

Unchecked errors: foreign data structure given for `parena`

**Parameters:**

- ↔ *parena* pointer to arena to dispose

**Returns:**

nothing

Here is the call graph for this function:

**4.2.3.4 void arena\_free (arena\_t \* arena)**

deallocates all storages belonging to an arena.

[arena\\_free\(\)](#) releases all storages belonging to a given arena.

Possible exceptions: `assert_exceptfail`

Unchecked errors: foreign data structure given for `arena`

**Parameters:**

↔ *arena* arena whose storages to be deallocated

**Returns:**

nothing

Here is the caller graph for this function:

**4.2.3.5 arena\_t\* arena\_new (void)**

creates a new arena.

[arena\\_new\(\)](#) creates a new arena and initialize it to indicate an empty arena.

Possible exceptions: `arena_exceptfailNew`

Unchecked errors: none

**Returns:**

new arena created

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