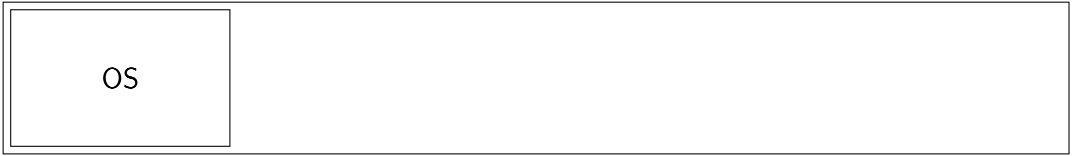
Memory management

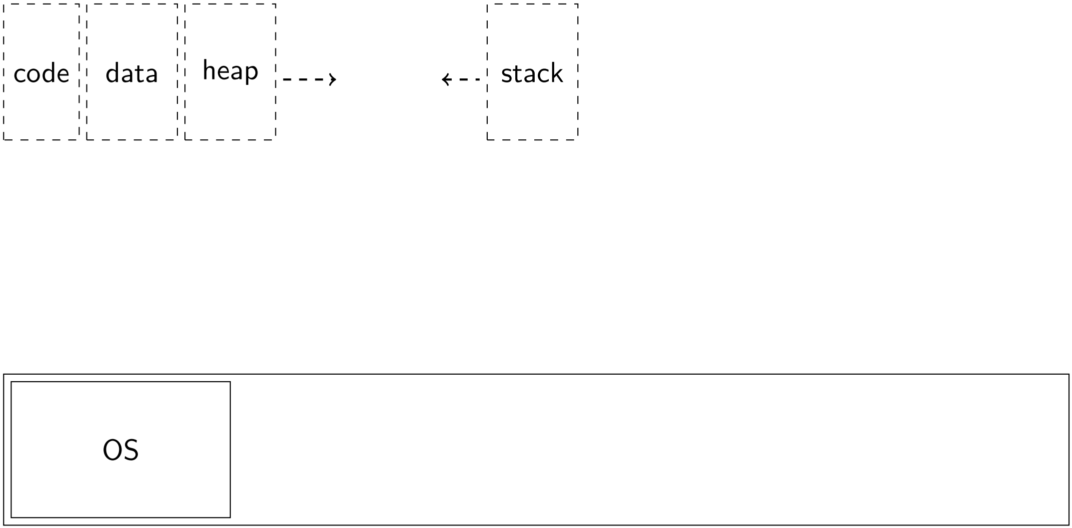
Johan Montelius

KTH

2021


OS

virtual memory and segmentation



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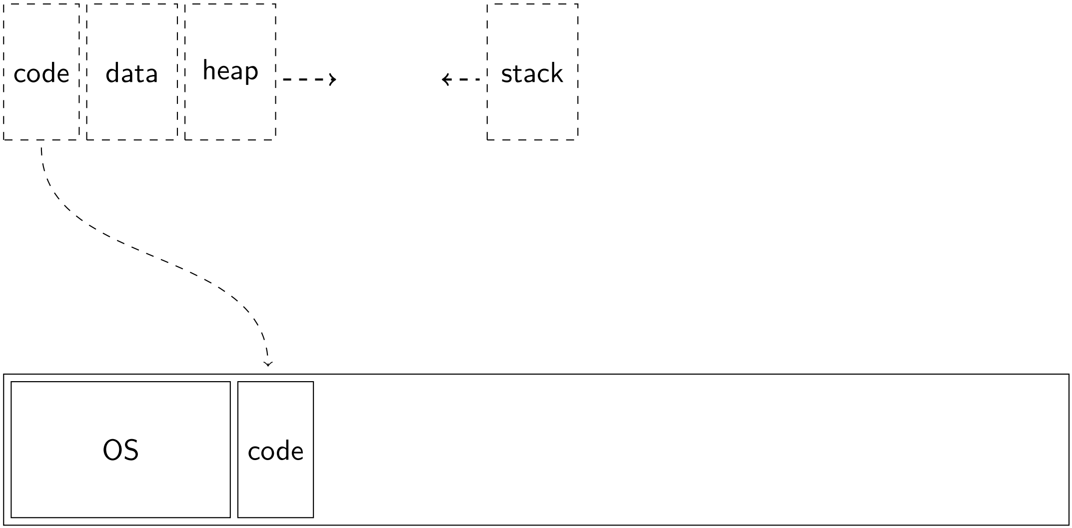

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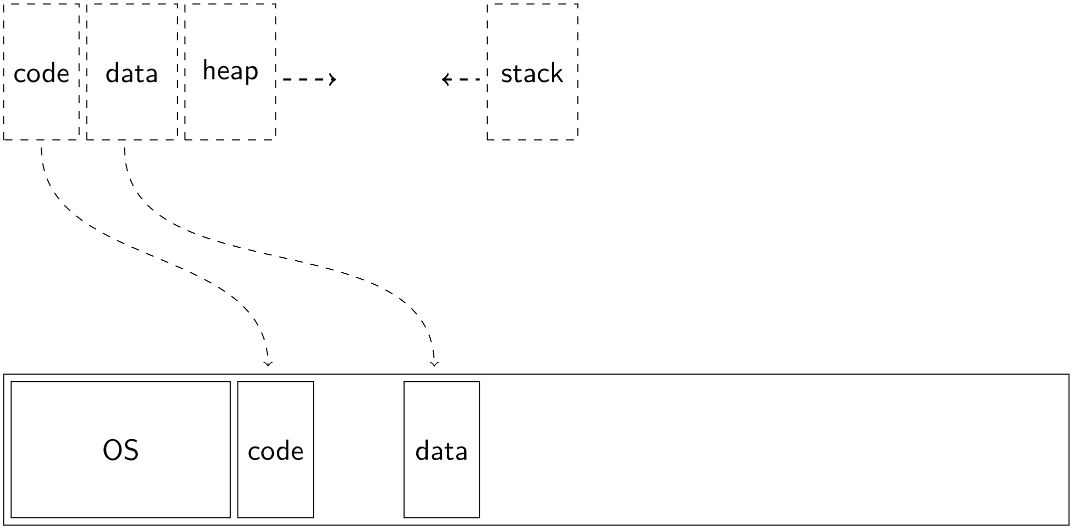

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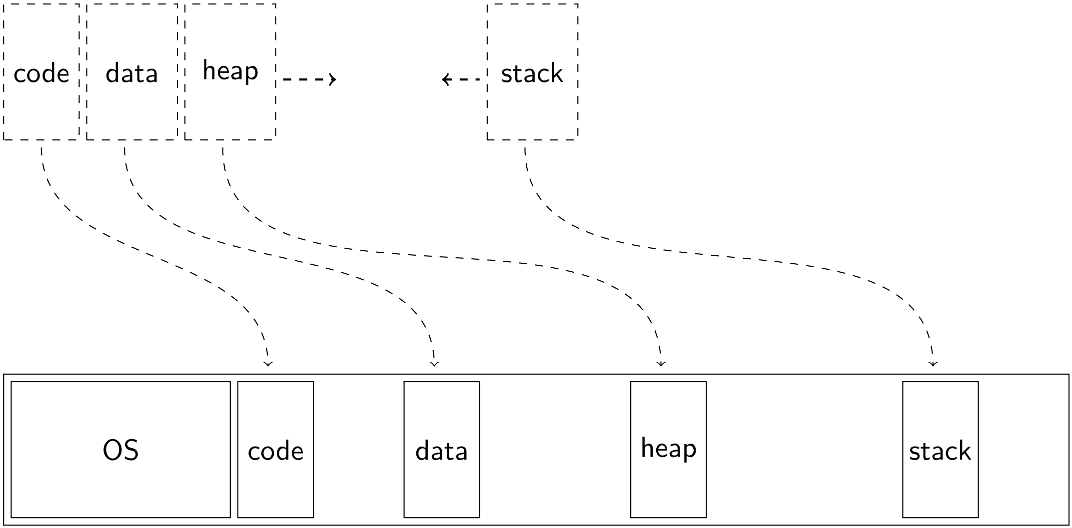

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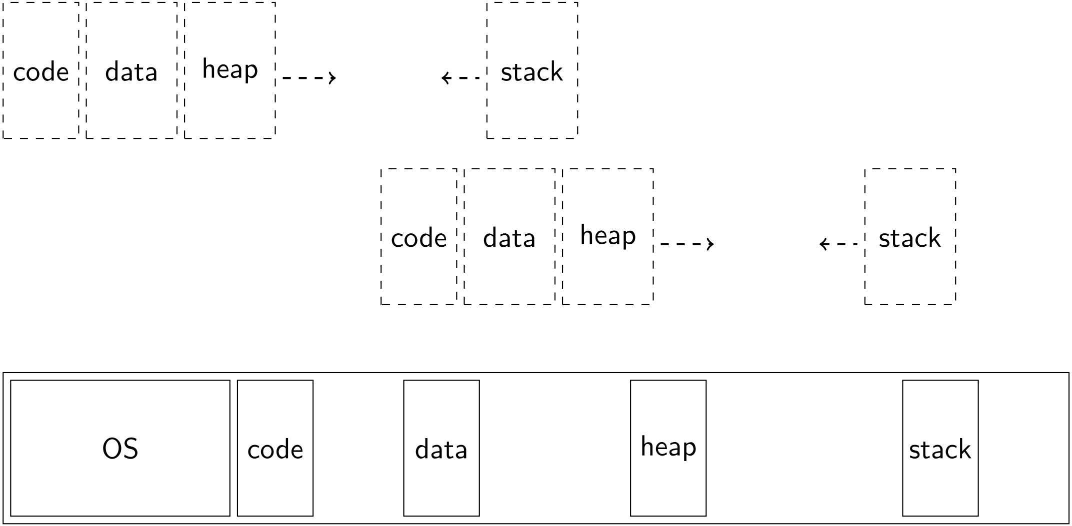

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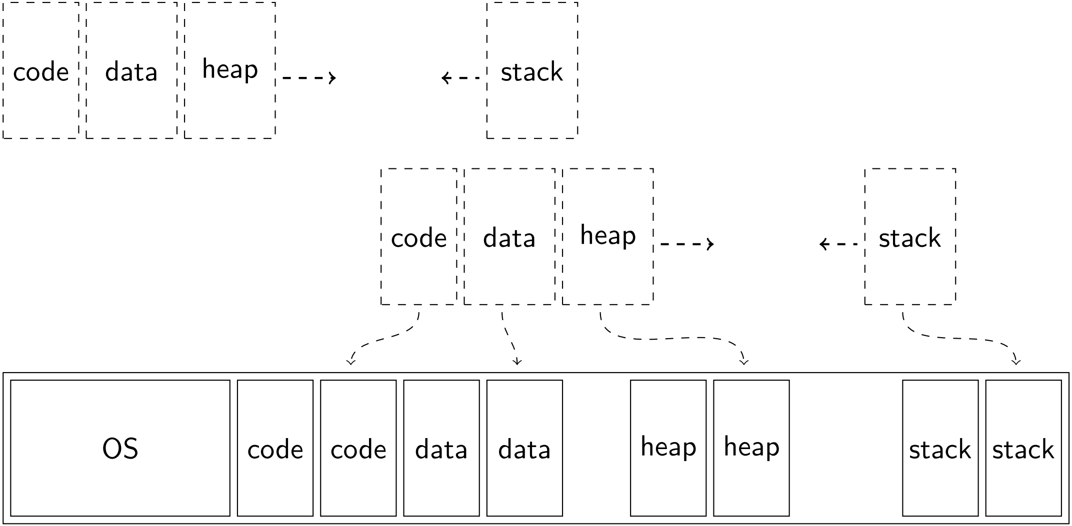

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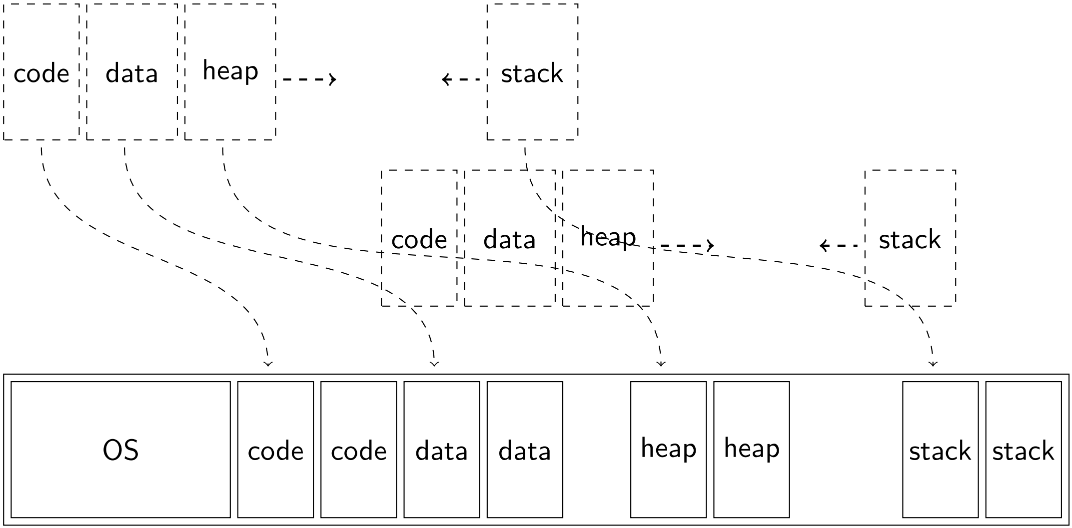
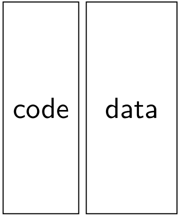


the process view



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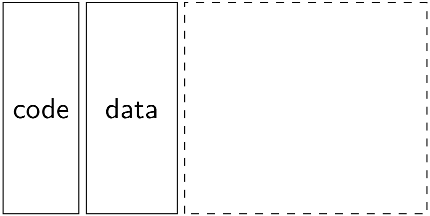

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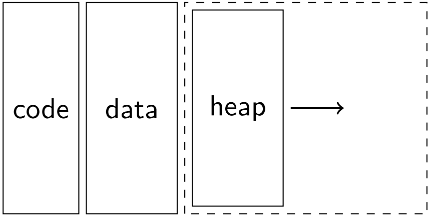

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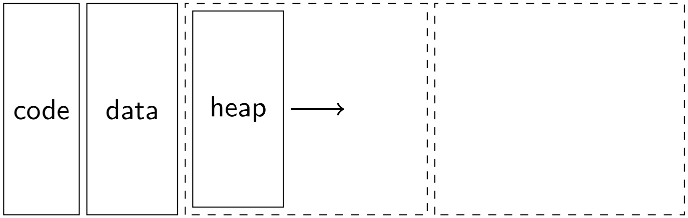

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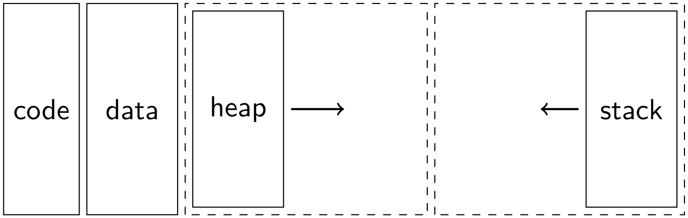

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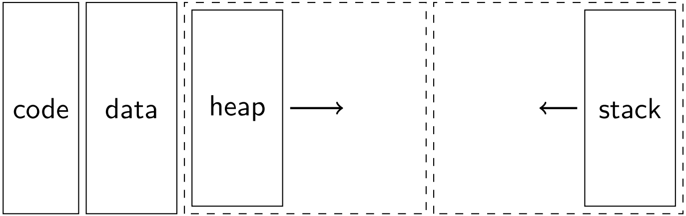

How do we obtain more memory for the heap data structures?

Linux system call

brk() and sbrk() change the location of the program break, which defines the end of the process's heap segment

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#include <unistd.h>

int brk(void *addr);
void *sbrk(intptr_t incr);
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Calling sbrk() with an increment of 0 can be used to find the current location of the program break.

C program - not the way to do it

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

int *allocate_array_please(int size) {

  return (int*)sbrk(size * sizeof(int));
}
```

a growing heap

a growing heap

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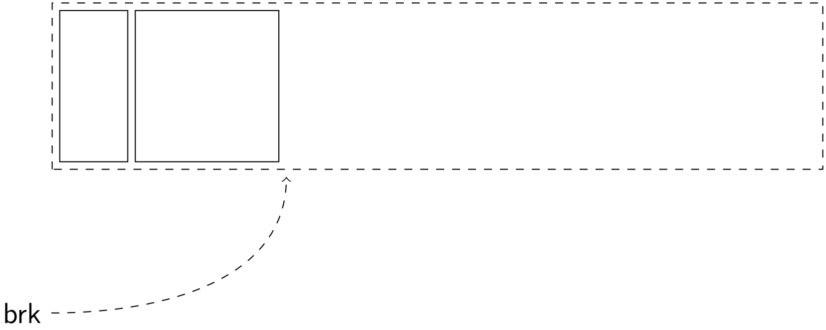

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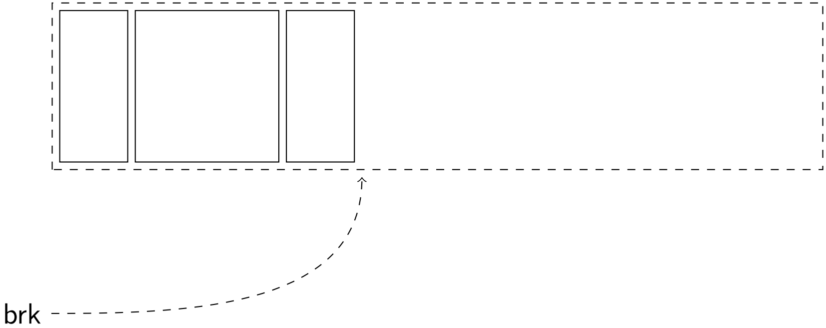

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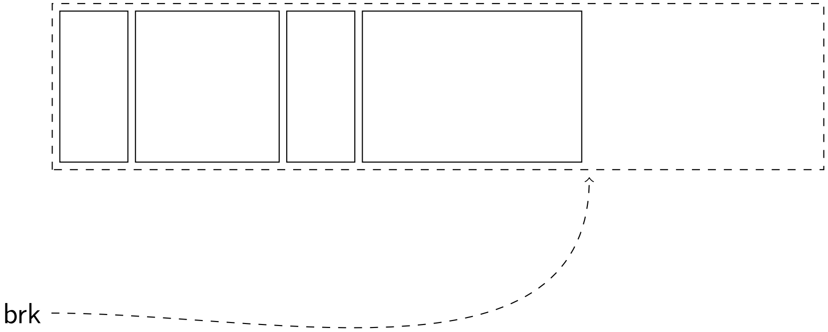

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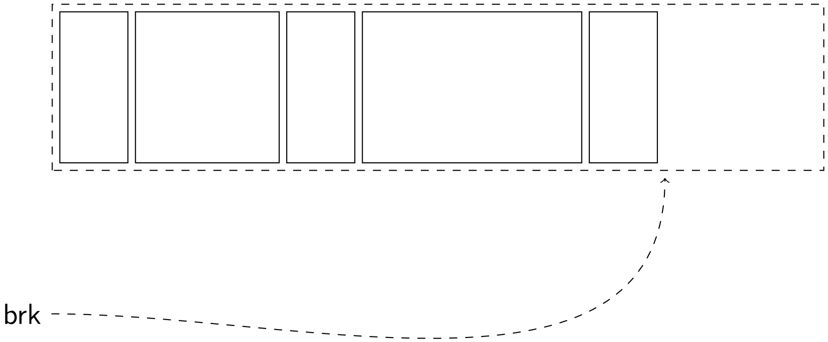

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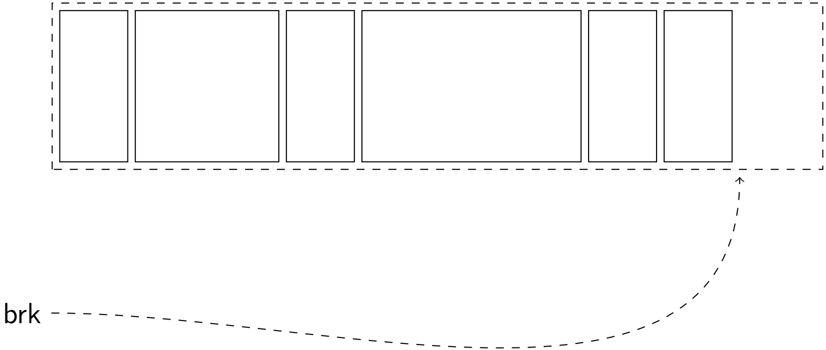

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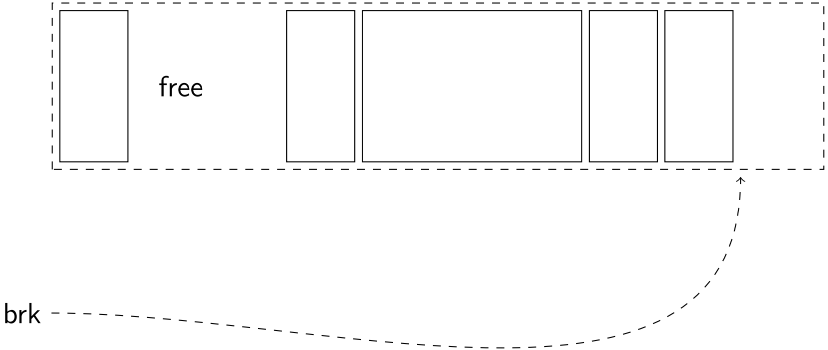

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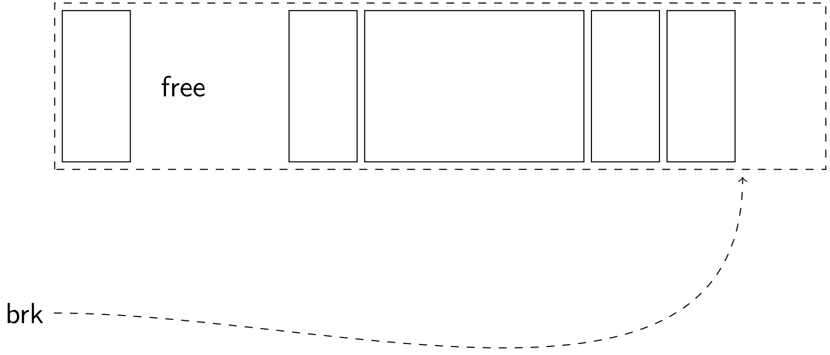

How do we reuse allocated memory?

C program

```
#include <stdlib.h>

int global = 42;

int main(int argc, char *argv[]) {
  if(argc < 2) return -1;
  int n = atoi(argv[1]);
  int on_stack[5] = {1,2,3,4,5};
  int *on_heap = malloc(sizeof(int)*n);
    :
}
```

The POSIX API

The malloc() function allocates size bytes and returns a pointer to the allocated memory. The memory is not initialized.

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The free() function frees the memory space pointed to by ptr, which must have been returned by a previous call to malloc(), ..

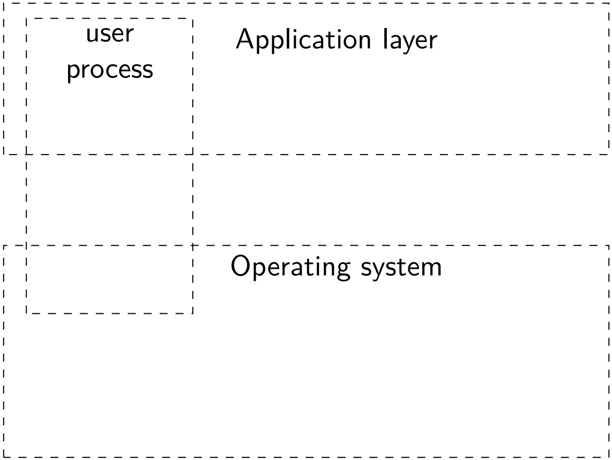
:

The operating system

Application layer

Operating system

The operating system



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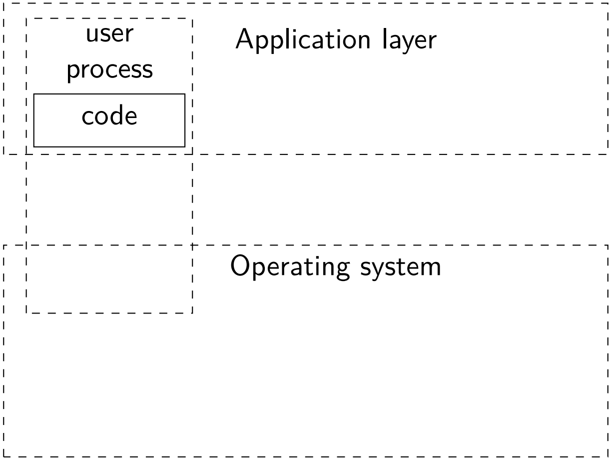

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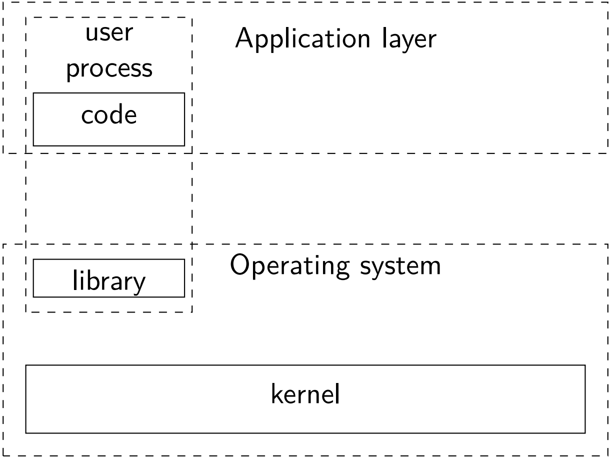

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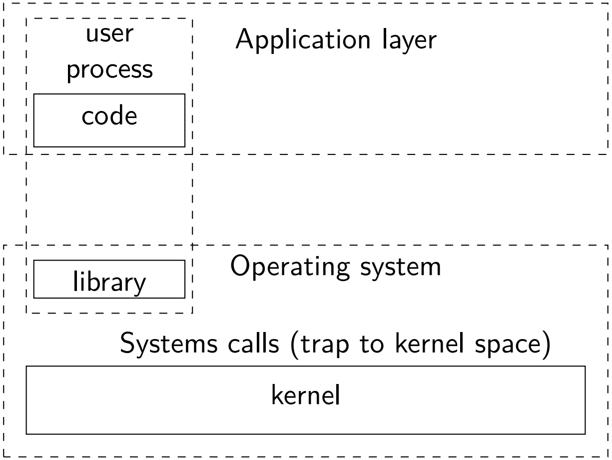

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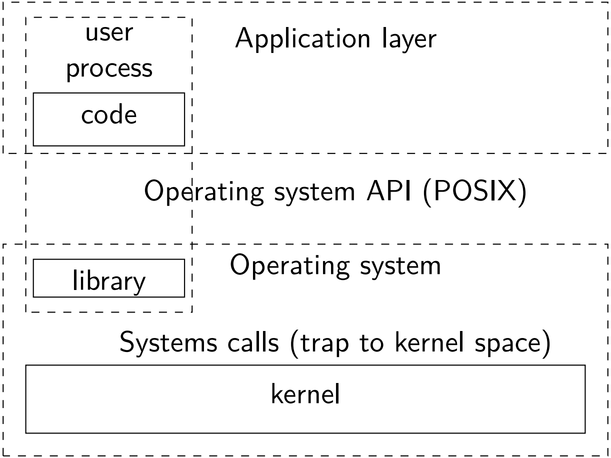

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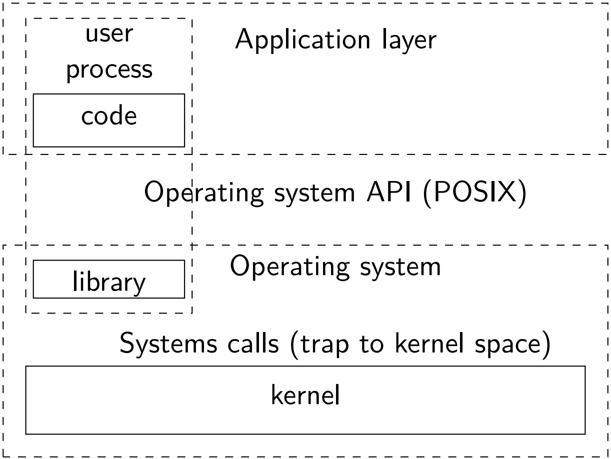

Library is often just a wrapper for the system call - sometimes more complex.

Memory hierarchy

User space program

Memory hierarchy

User space program

- -

Library routines

malloc() / free()

Memory hierarchy

User space program

Library routines — malloc() / free()

System calls — sbrk() / brk()

Memory hierarchy

User space program

`char a[10]` `structs person {int age; char name[20]}`

Library routines malloc() / free()

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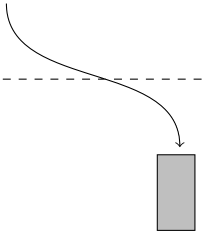

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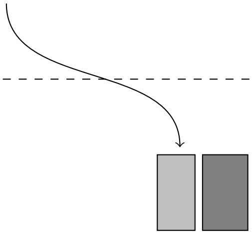

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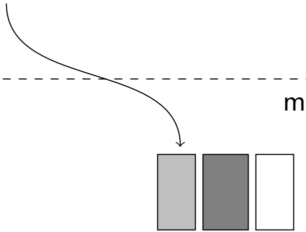

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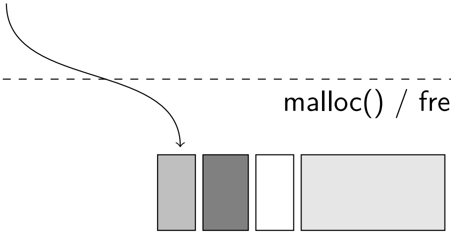

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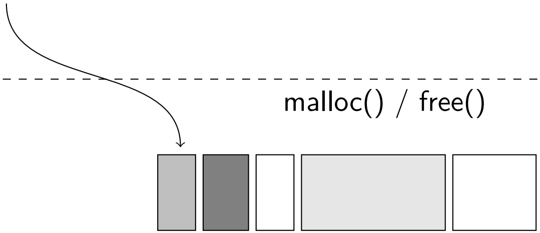

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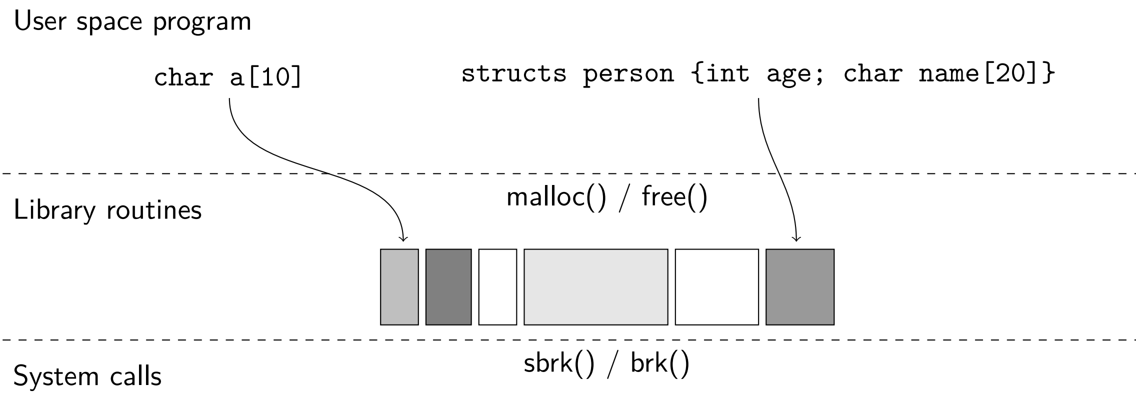

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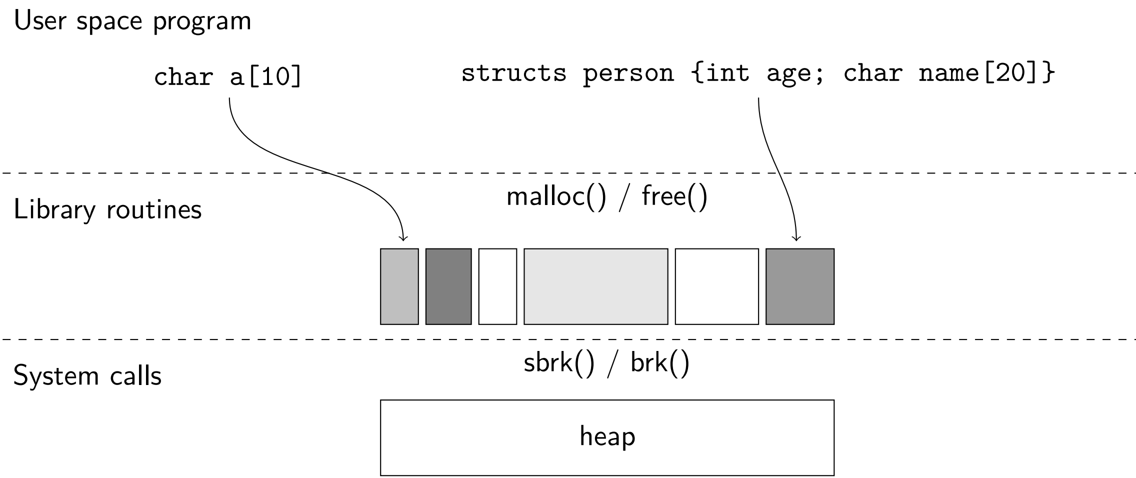

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A list of free blocks

Assume each free block holds a header containing: the size and a pointer to the next block.

```
typefdef struct __node_t {
  int     size;
  struct __node_t *next;
}
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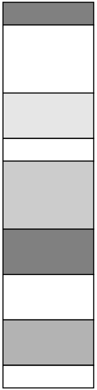

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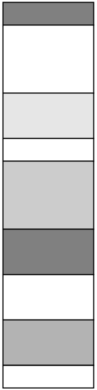

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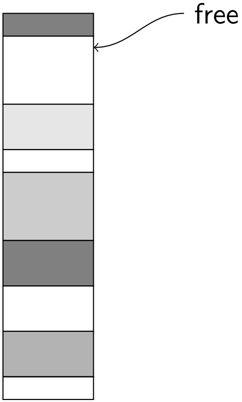

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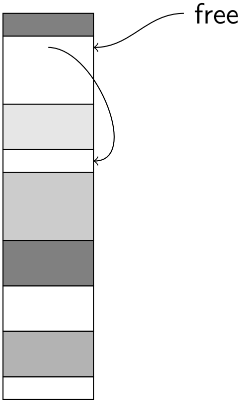


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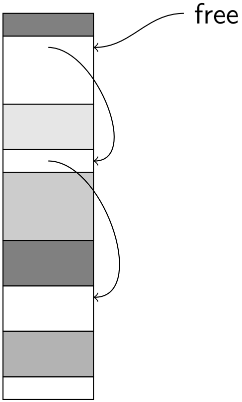

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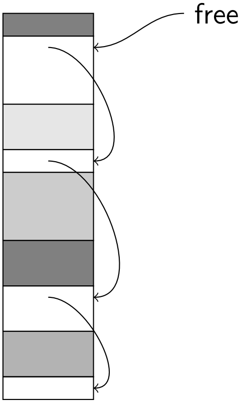

pick a suitable block

When we malloc we first search the free-list for a suitable block.

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char *buf = malloc(20)
```

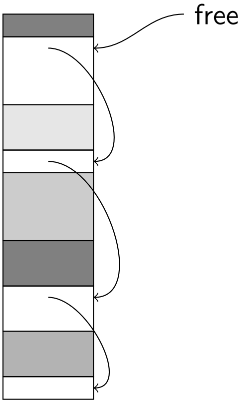

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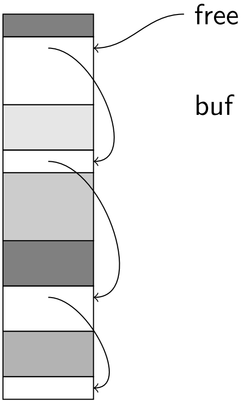

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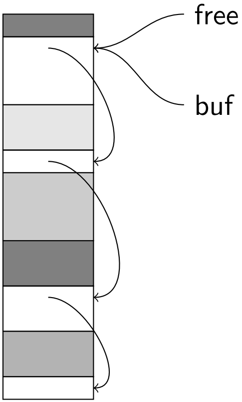

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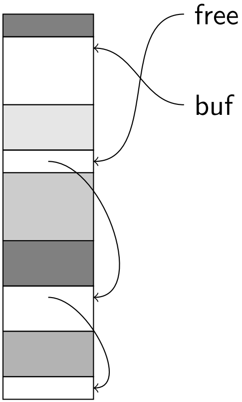
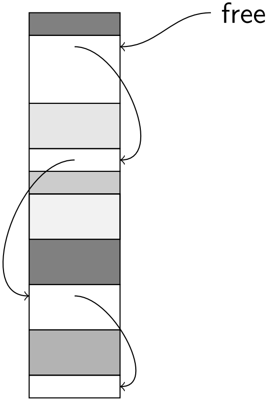


return a block

How do we return a block?

`free(this)`



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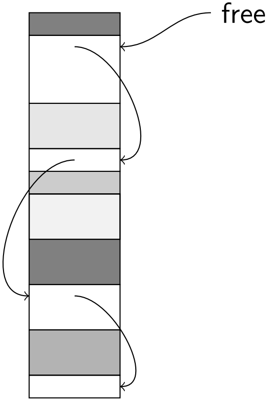

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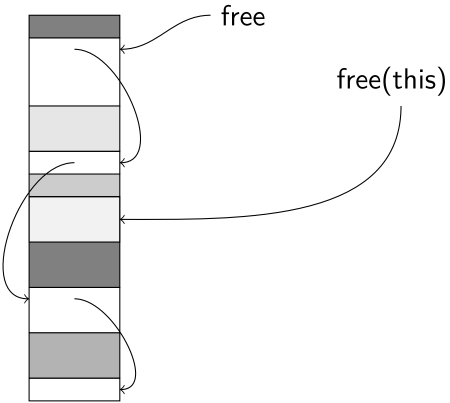

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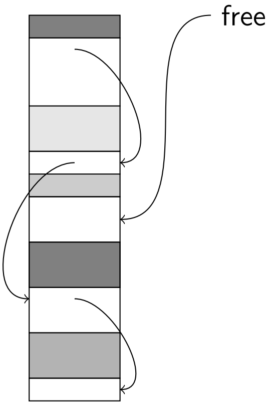

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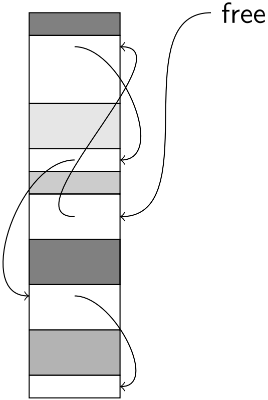

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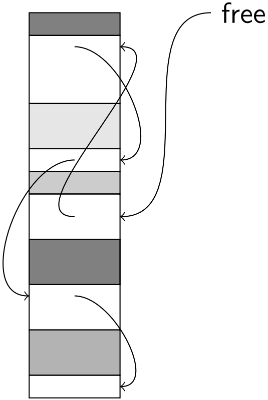


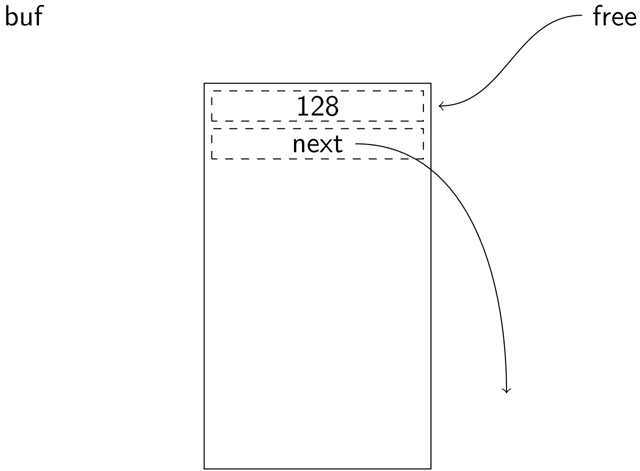
`free(this)`

What's the problem?

hidden information

```
 :
char *buf = malloc(128);
 :

 free(buf);
 :
```



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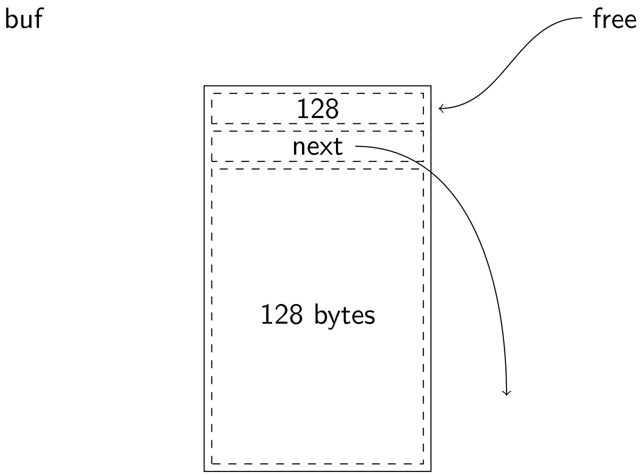

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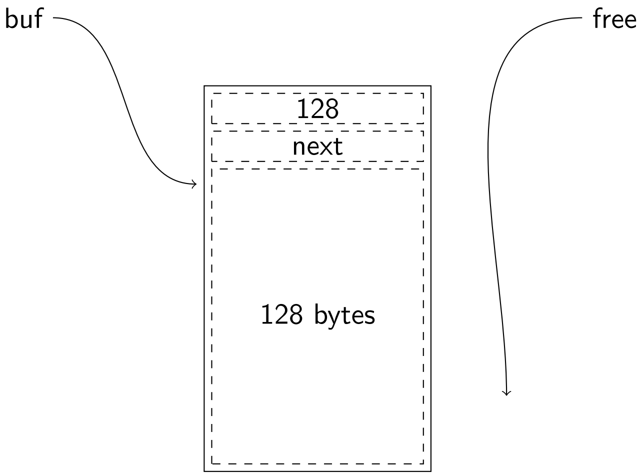
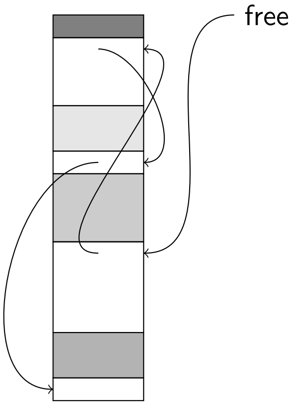


Malloc - find a suitable block and split it.



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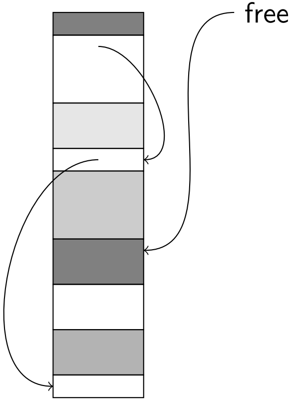

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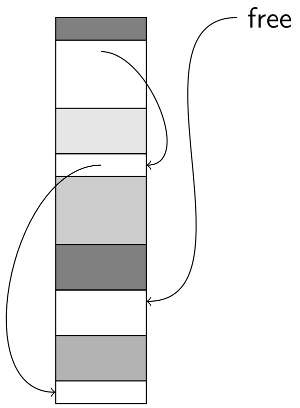

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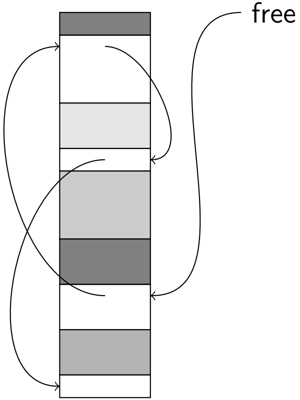

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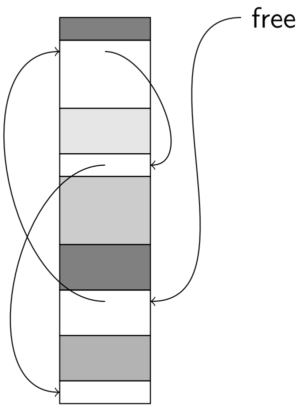
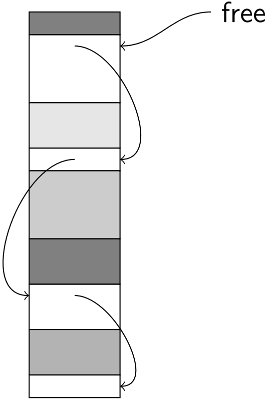


Coalescing - merging free blocks

When we return a block we need to merge it with adjacent free blocks - if any.



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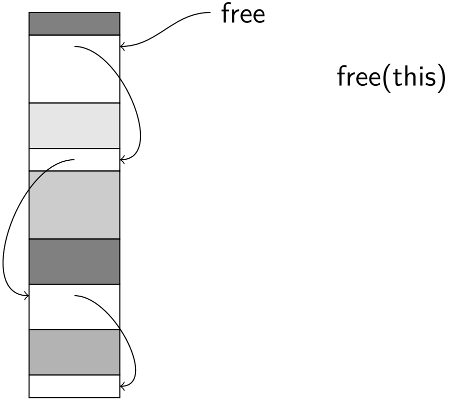

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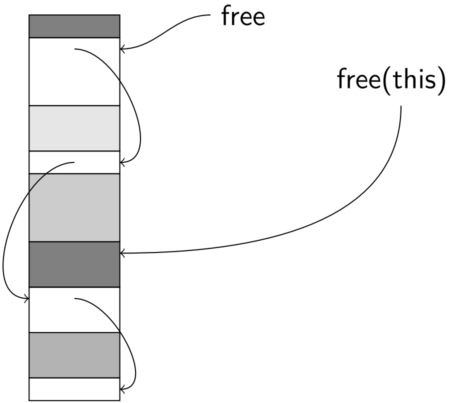

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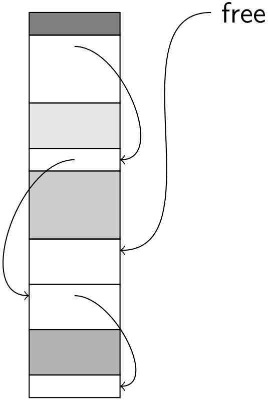

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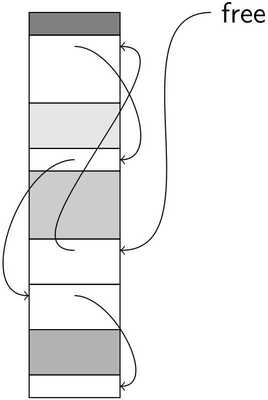

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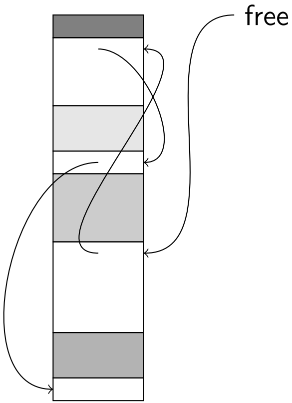

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You should know the pros and cons of these strategies.

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We can build our own allocator that is optimized for a given application.

malloc in GNU/Linux

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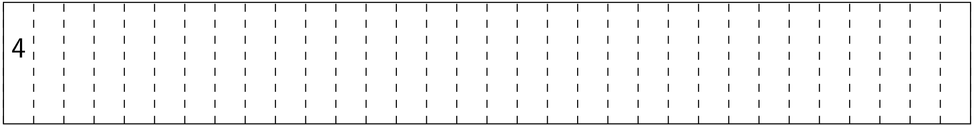

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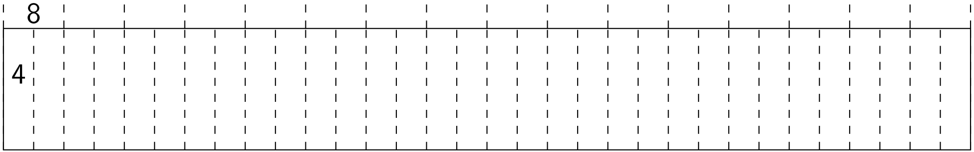

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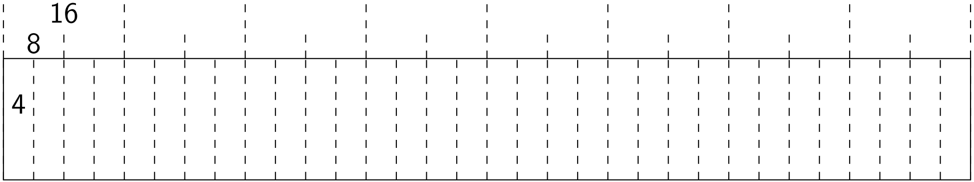

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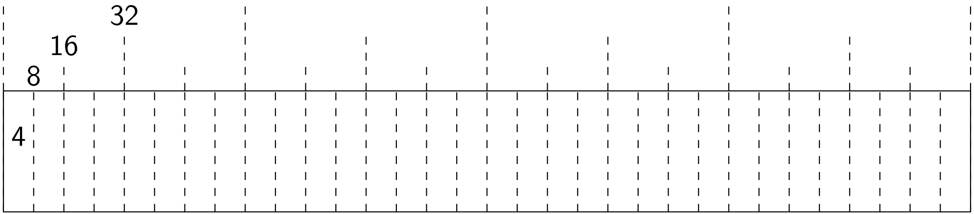

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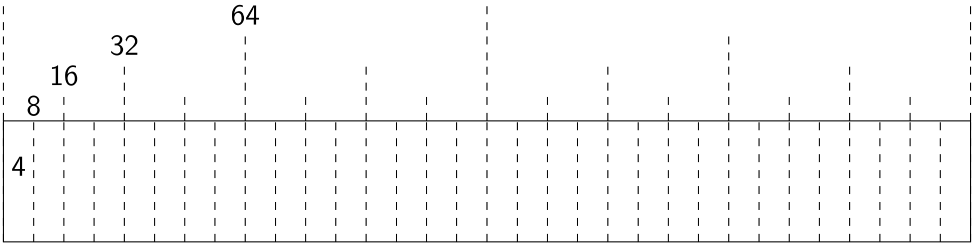

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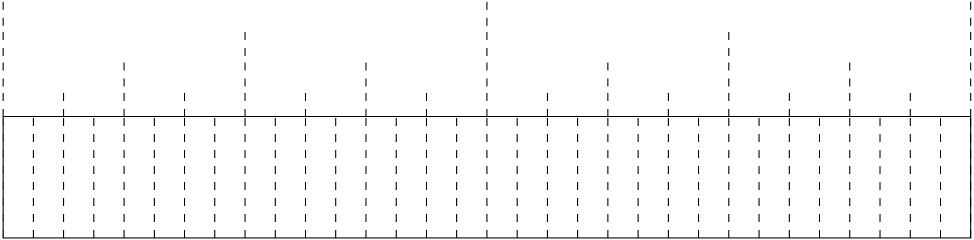

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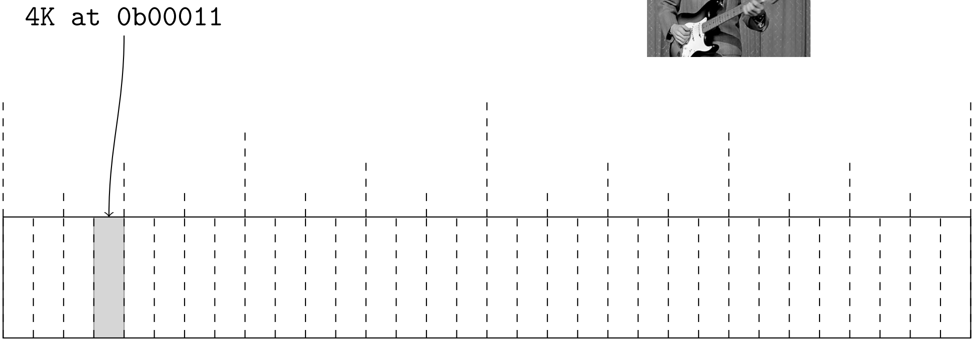

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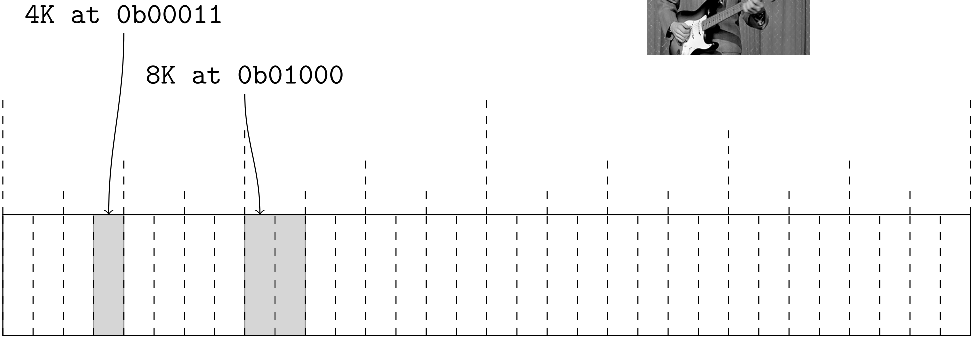

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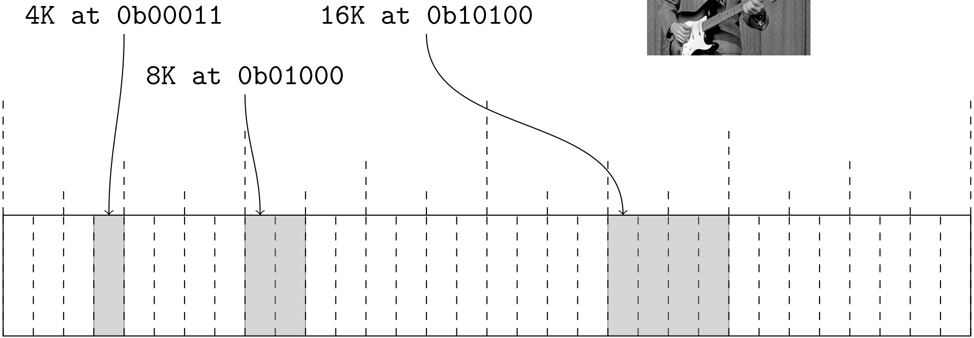

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Linux uses Buddy allocations when managing physical memory - check `/proc/buddyinfo`*.*

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Originally from 4.2BSD, default in OSX where malloc() uses mmap() to allocate memory.

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