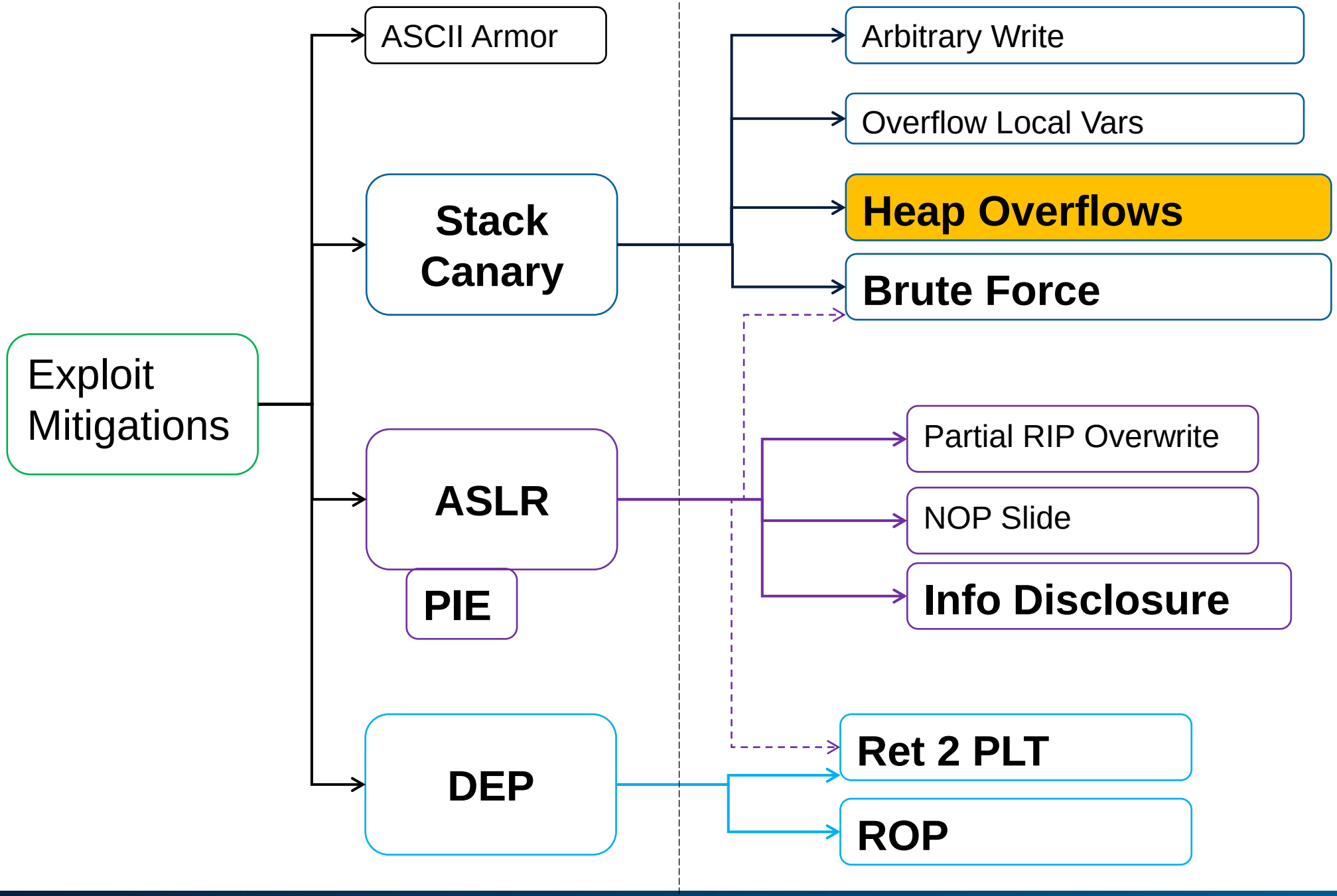
Defeat Exploit Mitigation Heap Intro

HEAP


Exploit Mitigations
ASCII Armor
Stack Canary
ASLR
PIE
DEP
Arbitrary Write
Overflow Local Vars
Heap Overflows
Brute Force
Partial RIP Overwrite
NOP Slide
Info Disclosure
Ret 2 PLT
ROP

Heap Exploitation

This slidedeck is not completely technically accurate

Should give an overview of heap exploitation concepts

Heap Introduction

What is a heap?

- malloc() allocations
- Fullfill allocating and deallocating of memory regions

Heap usage:

- Global variables (live longer than a function)
- Can be big (several kilobytes or even megabytes)

Reminder: Stack usage:

- Function-local variables
- Relatively small (usually <100 or <1000 bytes)

Heap Introduction

Heap:

- Dynamic memory (allocations at runtime)
- Objects, big buffers, structs, persistence, large things
- Slow, manually

Stack:

- Fixed memory allocations (known at compile time)
- Local variables, return addresses, function args
- Fast, automatic

Heap Introduction

Userspace/OS can implement his own memory allocator

- Linux: ptmalloc2 (previously dlmalloc)
- Samba: talloc
- FreeBSD and Firefox: jemalloc
- Google: tcmalloc
- Solaris: libumem

- Basically: mmap() a memory block and manage it

Heap Introduction

Heap in Linux

- Heap implementation is usually implemented in GLIBC
- Current Heap allocator implementation: **ptmalloc2**
  - Based on dlmalloc
  - From GLIBC 2.4 onwards

- Previous / Old:
  - Doug Lea’s memory allocator
  - **Dlmalloc**
  - Note: If you research heap exploits, check what allocator is assumed to be used

Heap introduction

malloc(): Get a memory region

free(): Release a memory region

We only cover manual allocations

- Not: Automatic garbage collection
- (Garbage collection is just an automatic free() by using reference counting)

Heap Interface

How does heap work?

void *ptr;

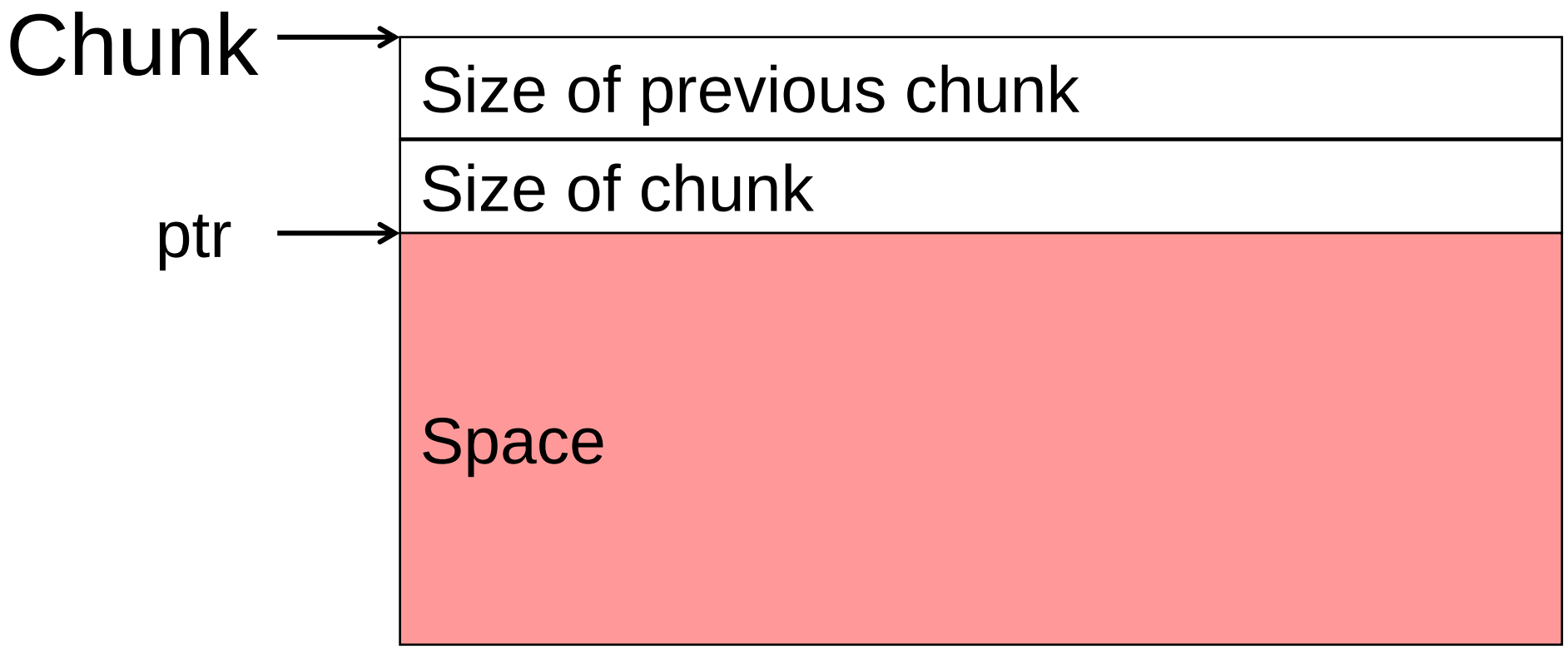
ptr = malloc(len)

- Allocated “len” size memory block
- Returns a pointer to this memory block

free(ptr)

- Tells the memory allocator that the memory block can now be re-used
- Note: ptr is NOT NULL after a free()

Heap Interface



Heap

What is a heap allocator doing?

- Allocate big memory **pages** from the OS
- Manage this **pages**

- Split the **pages** into smaller **chunks**
- Make these **chunks** available to the program

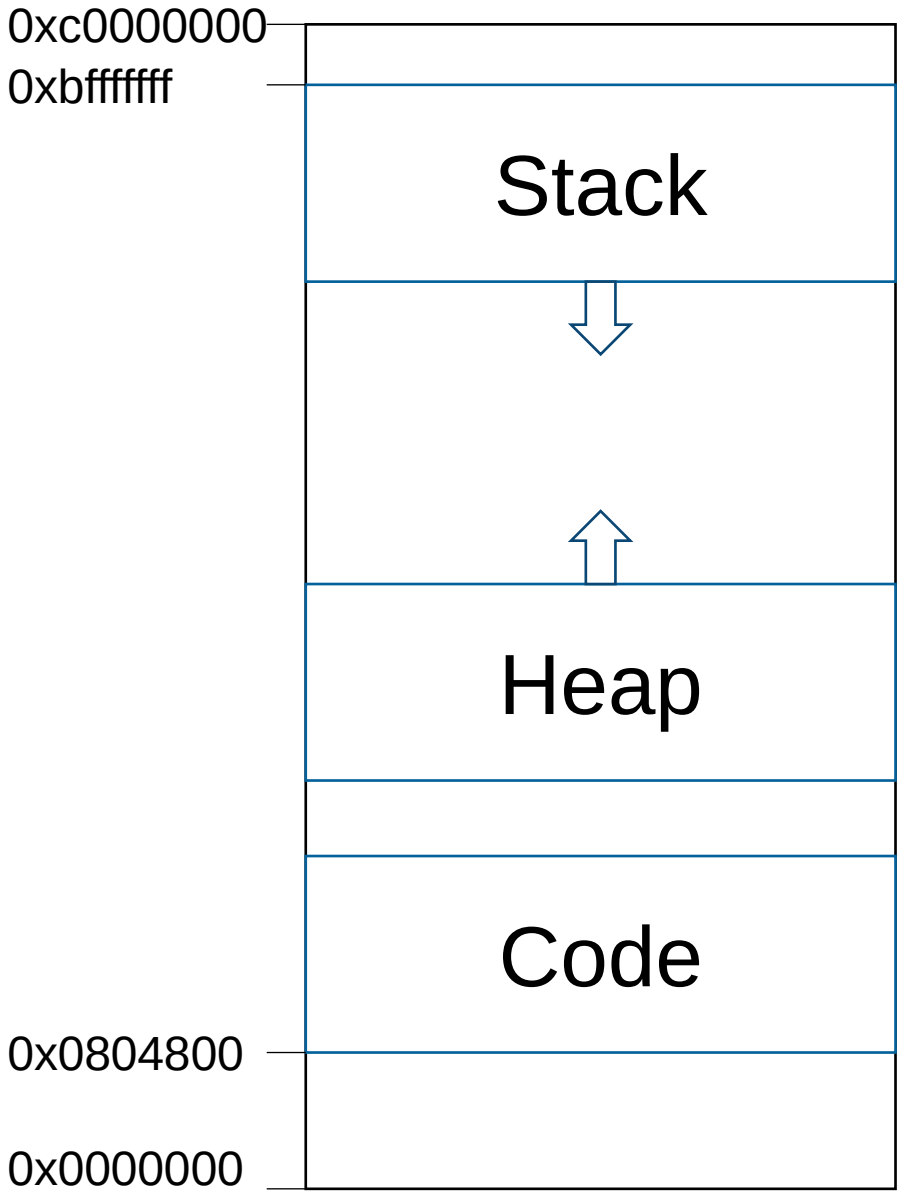
Heap – Simplified Example

Heap Introduction

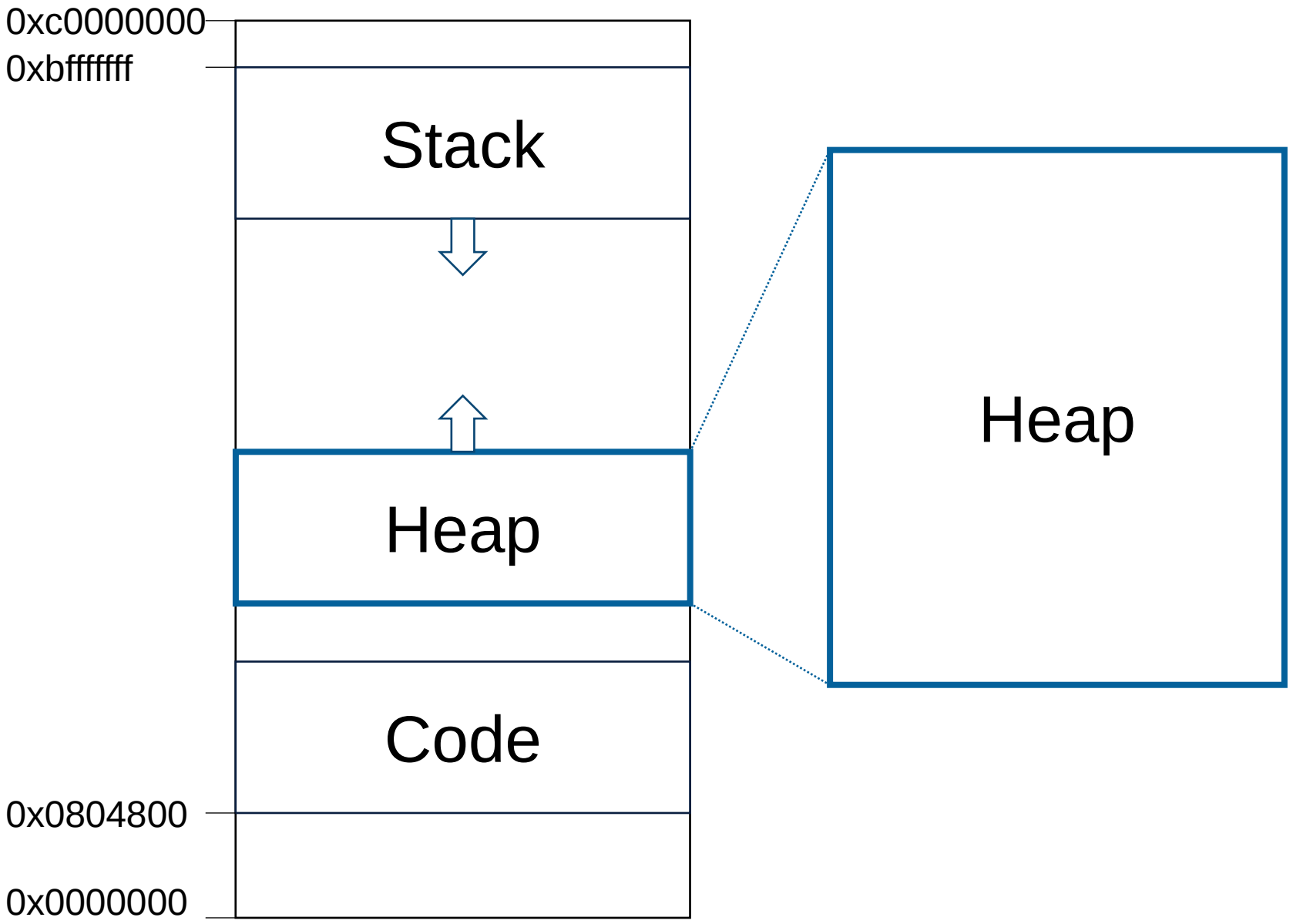
How is this implemented?

- The heap implementation gets a (big) block of flat/unstructured memory (**page** / pages)
- Partition the heap/page into **bin’s**
- A **bin** has **chunks** of the same size

Heap: Memory Layout



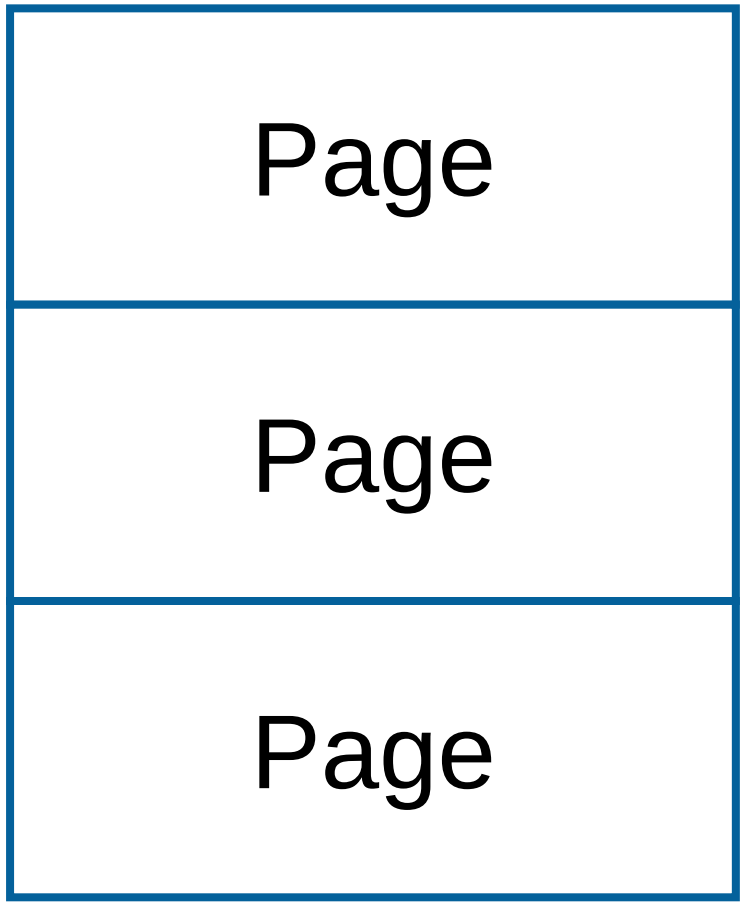
Heap: Memory Layout



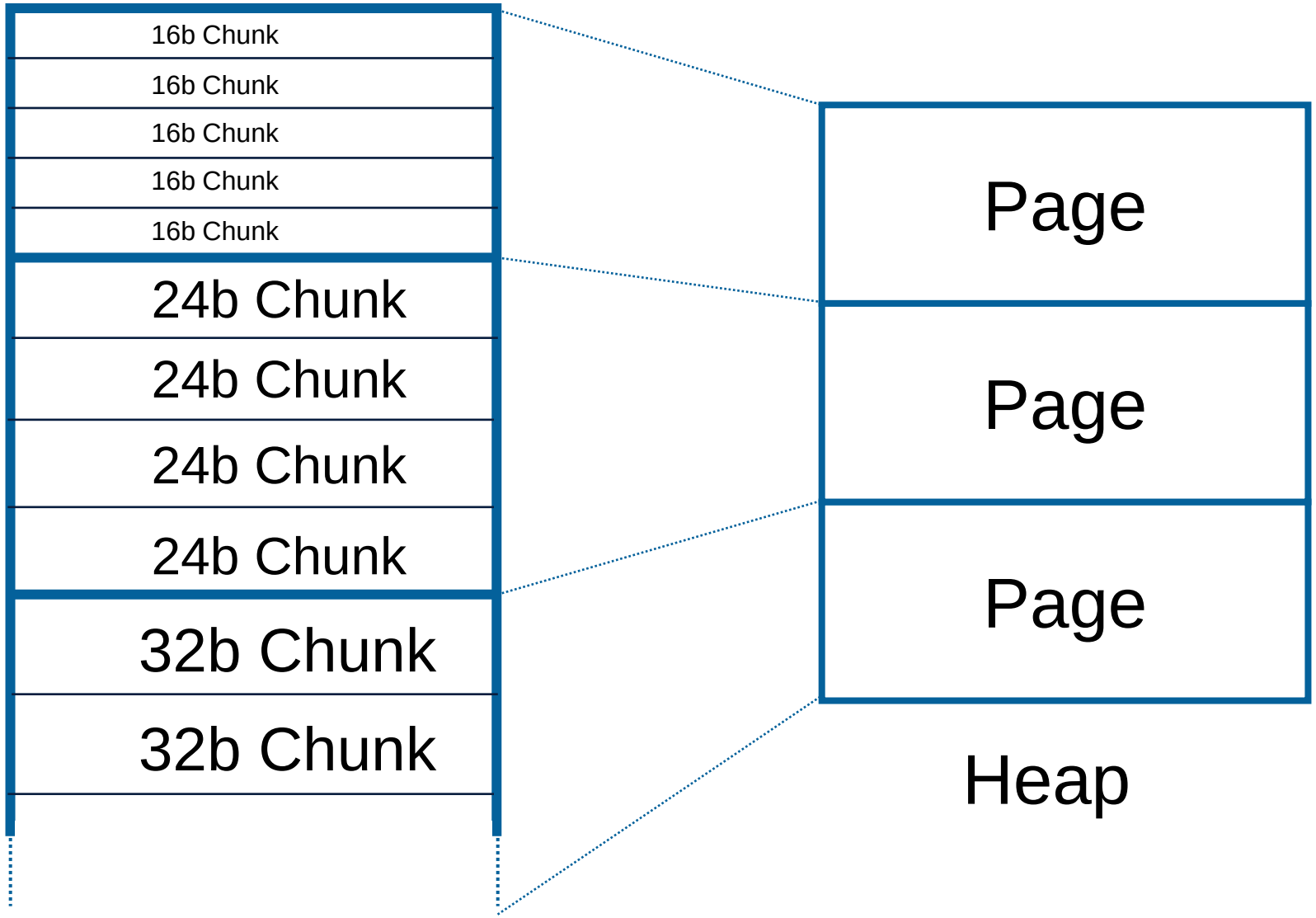
Heap: Memory Layout

Page:

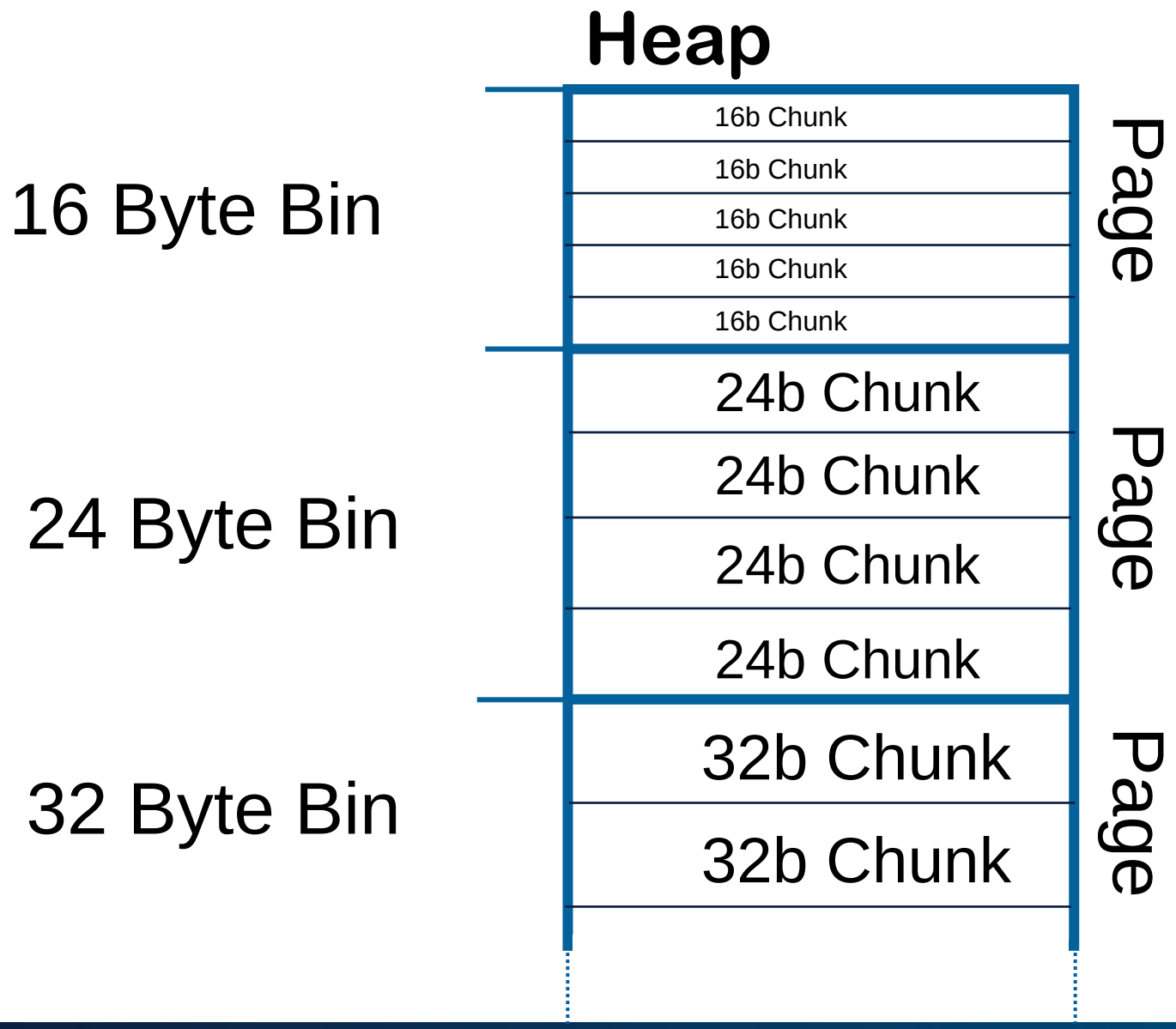
- A memory page
- Usually **4k**
- Can also be 2 Megabytes or other
- Allocated via sbrk() or mmap()



Heap: Memory Layout



Heap: Oversimplified example



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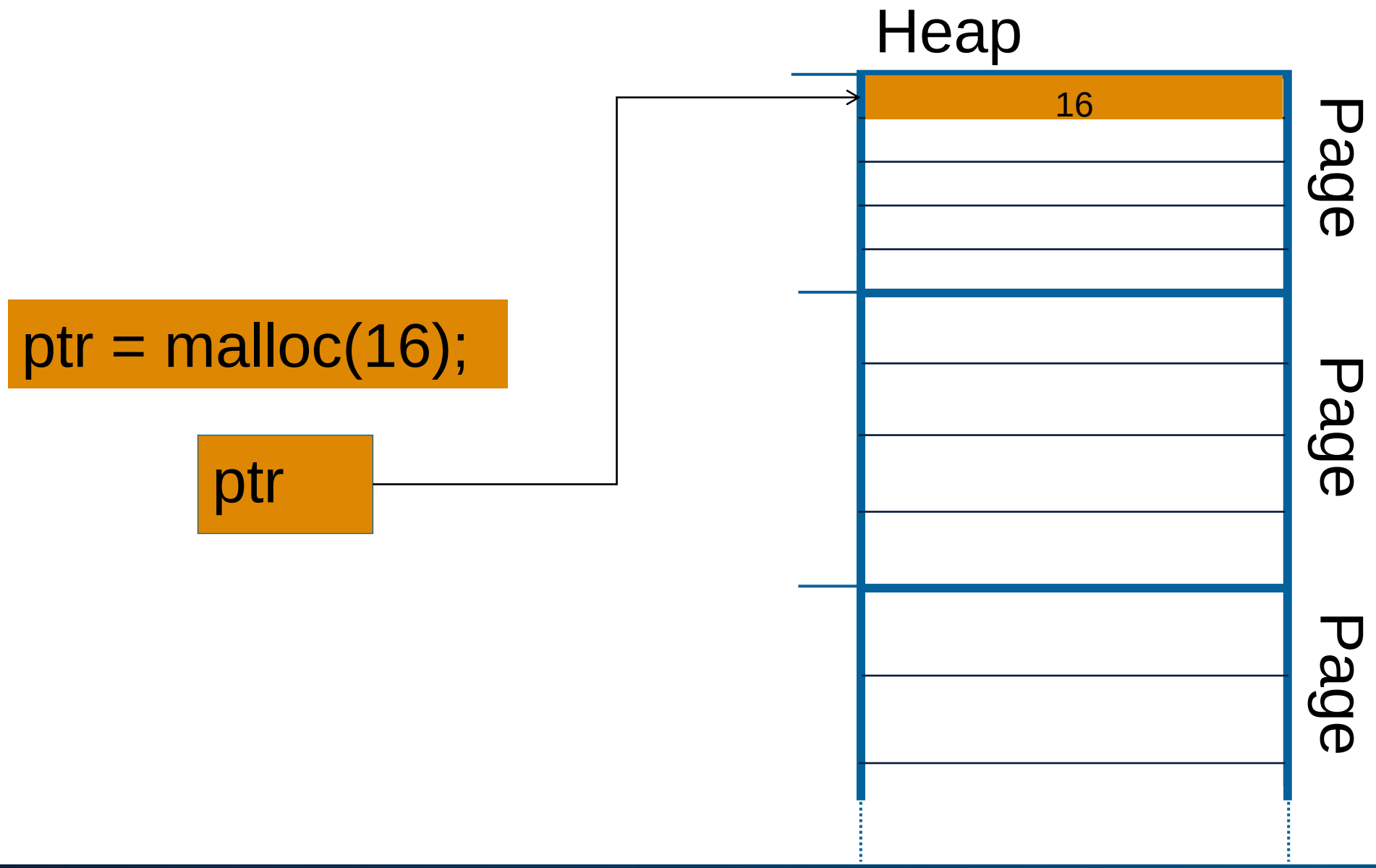

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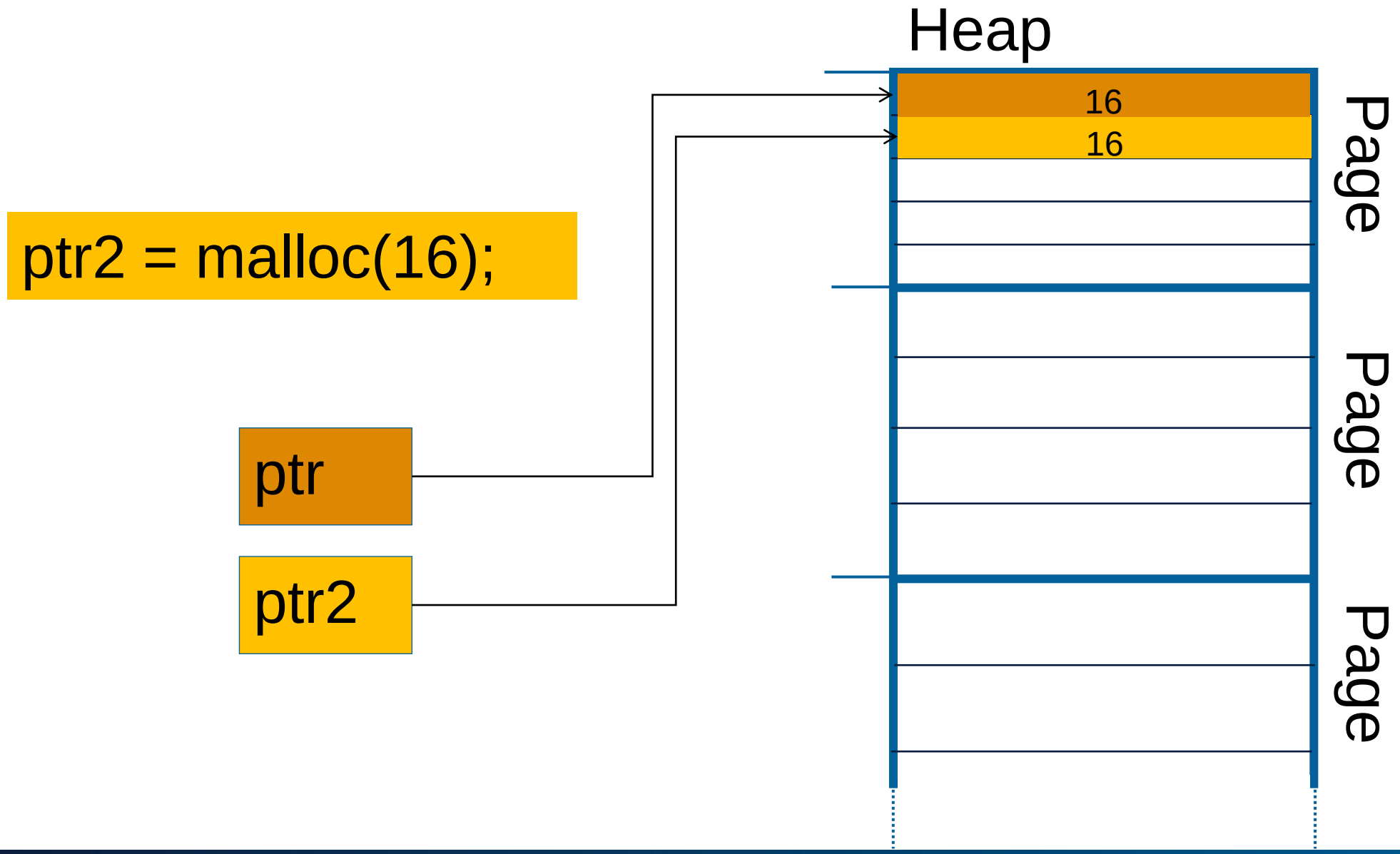

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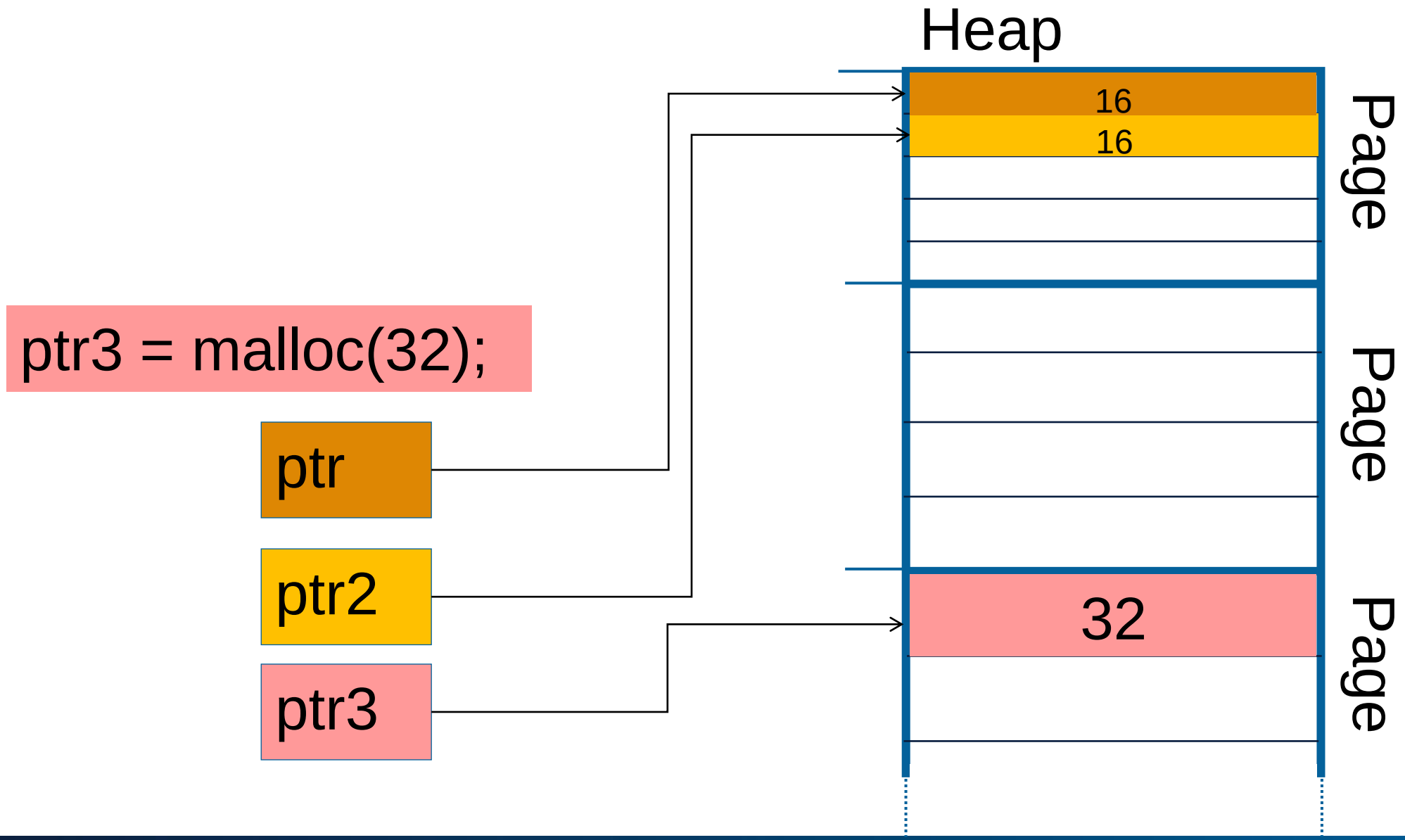

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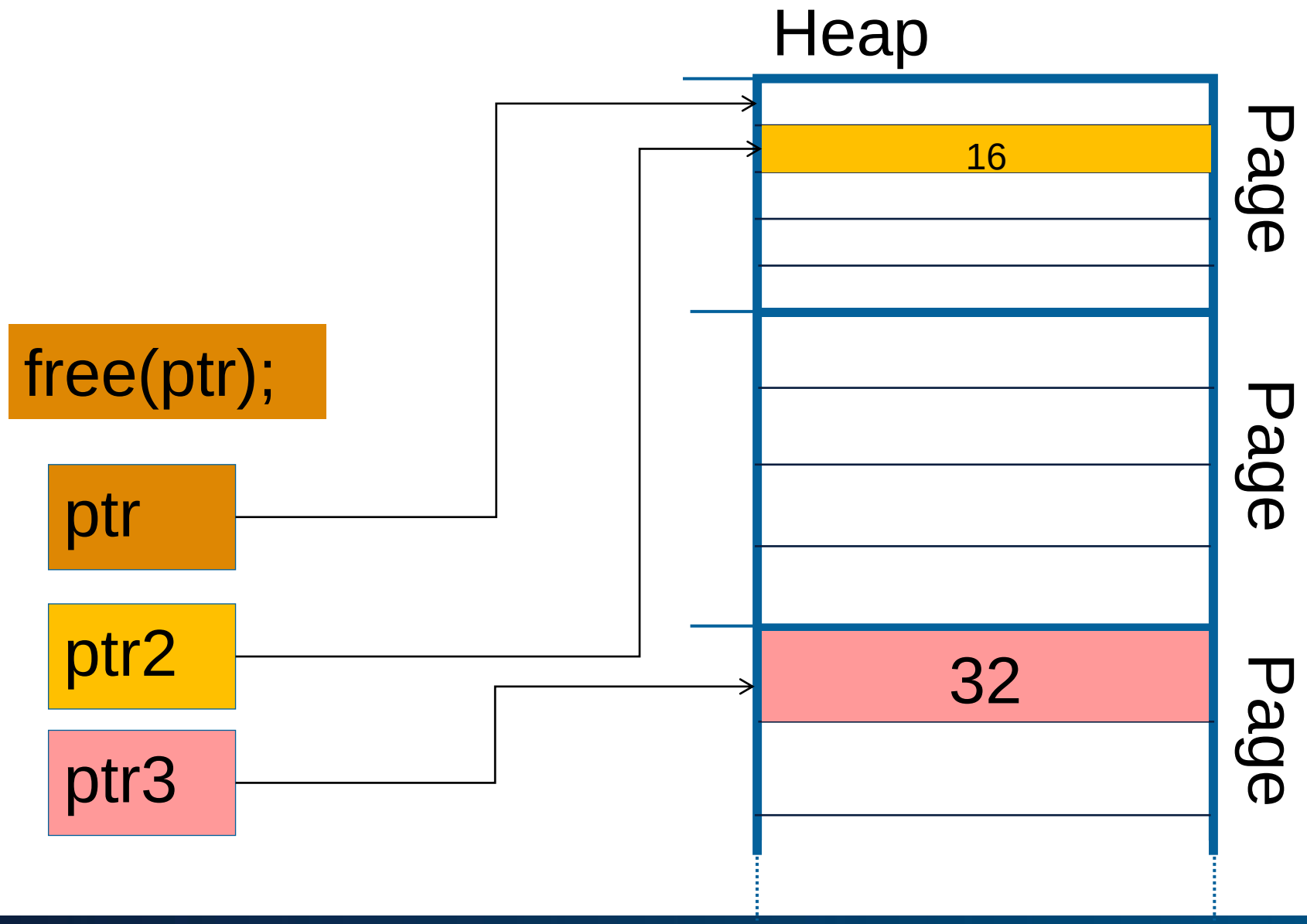

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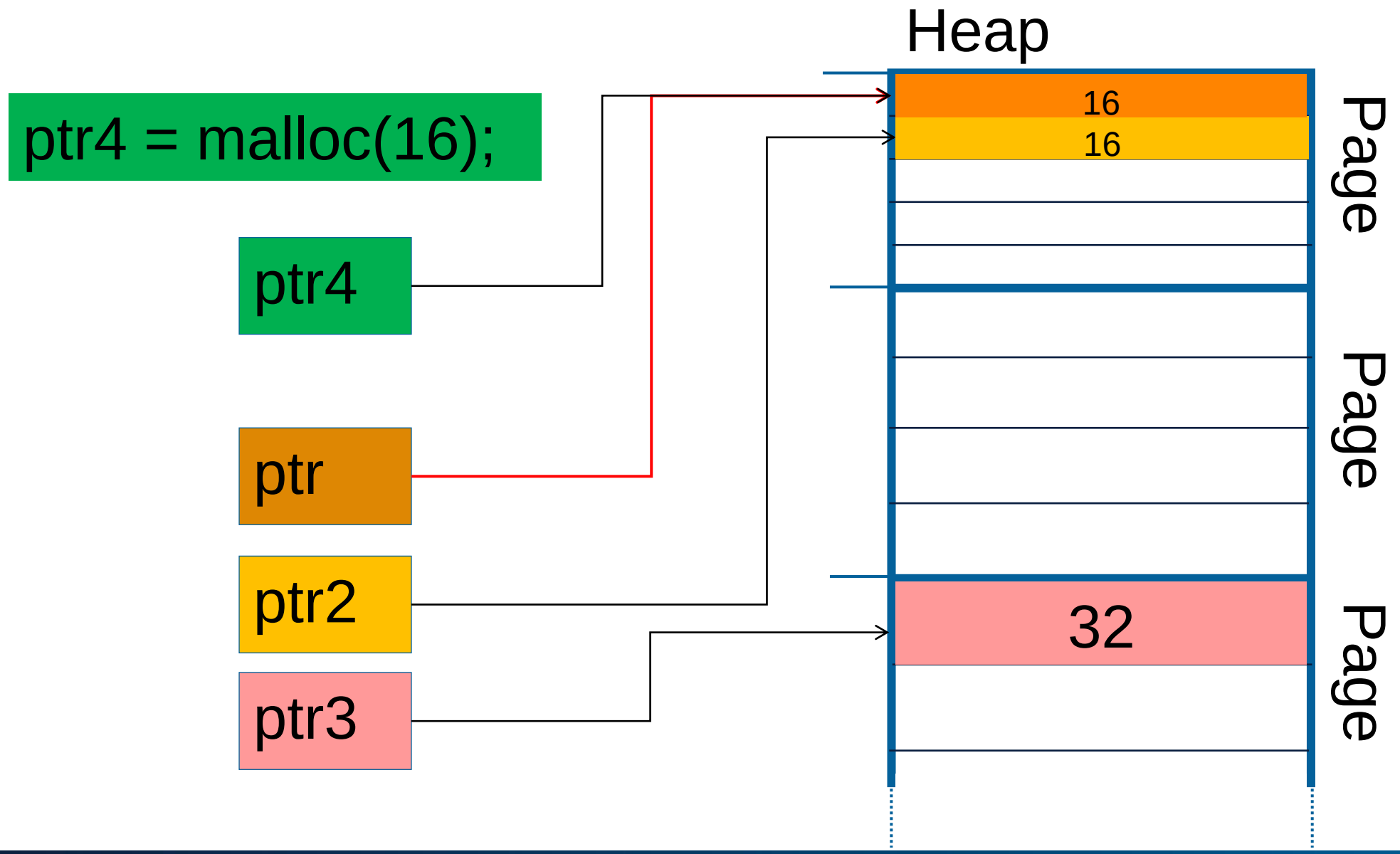


Heap - Recap

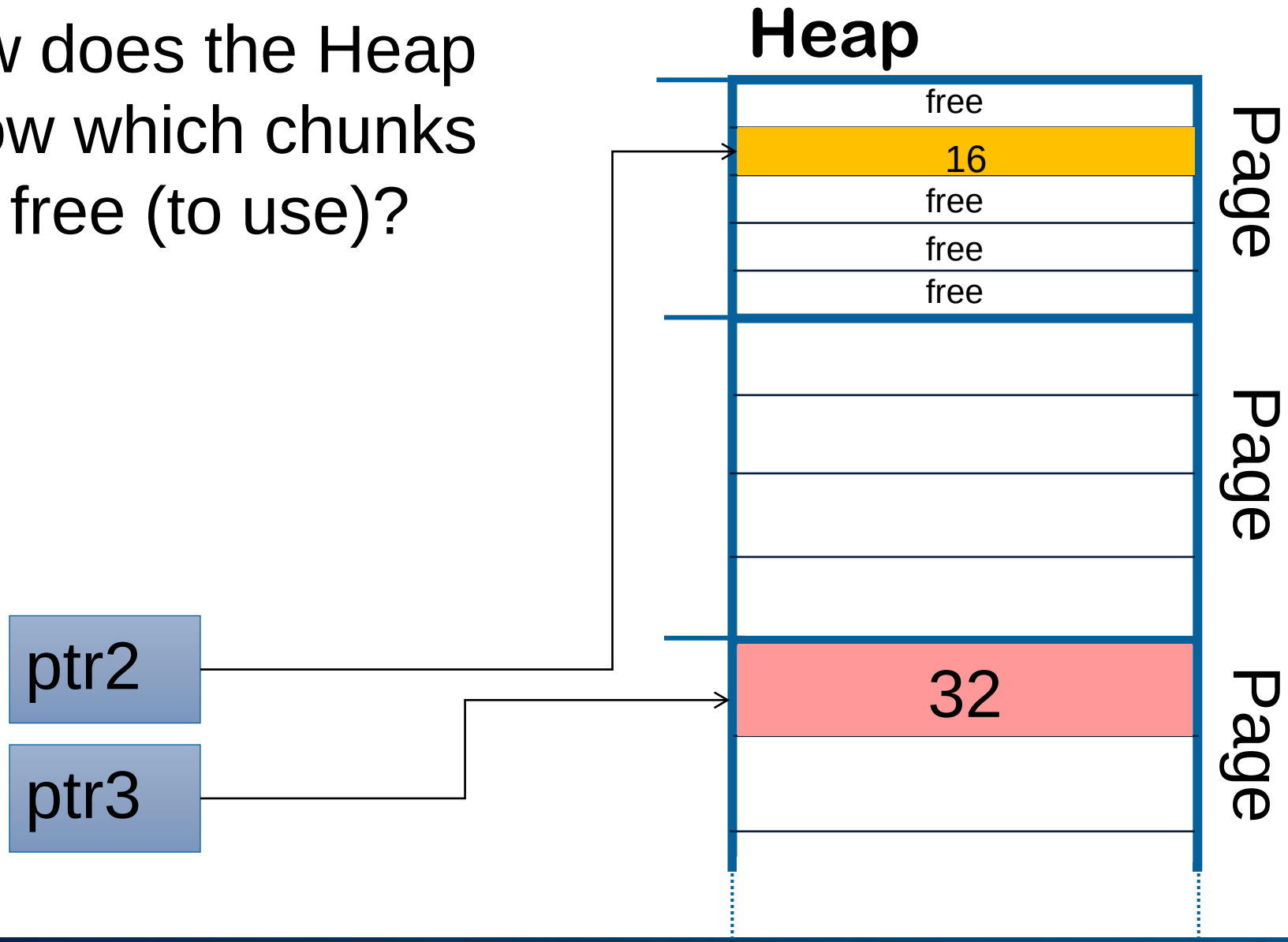
Recap:

- Heap divides big (4k) memory pages into smaller chunks
- Heap gives these chunks to the program on request
- A pointer to a heap allocation points to the data part (the chunk contains more metadata)

Heap Memory Management

Heap Memory Management

How does the Heap
Know which chunks
Are free (to use)?



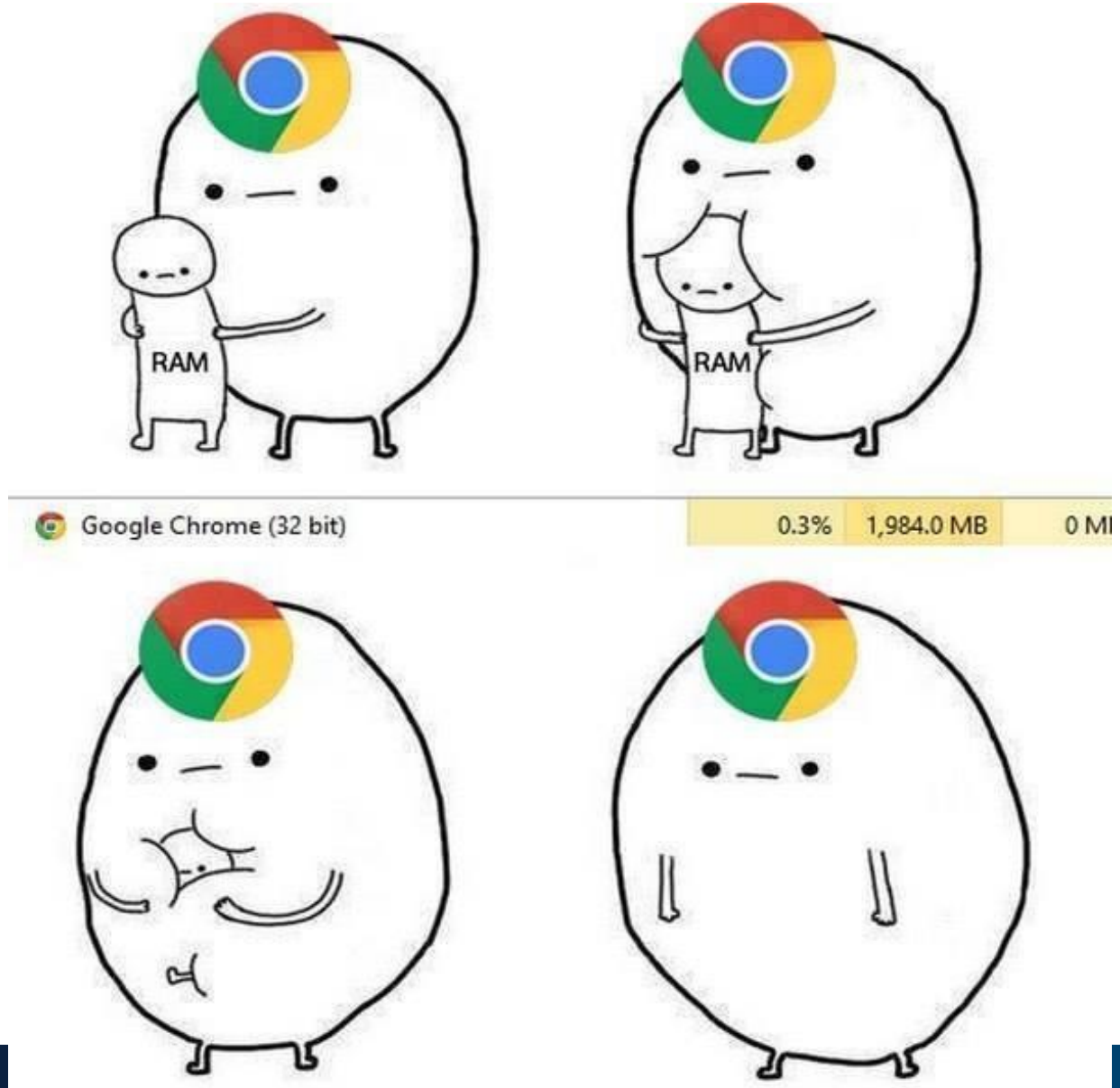
Heap Memory Management

Heap allocator requirements:

- Should be **quick** to fulfill malloc() and free()
- Should **not waste** memory by managing memory

- Also: No bugs, correct, low-fragmentation, etc.

Heap Memory Management



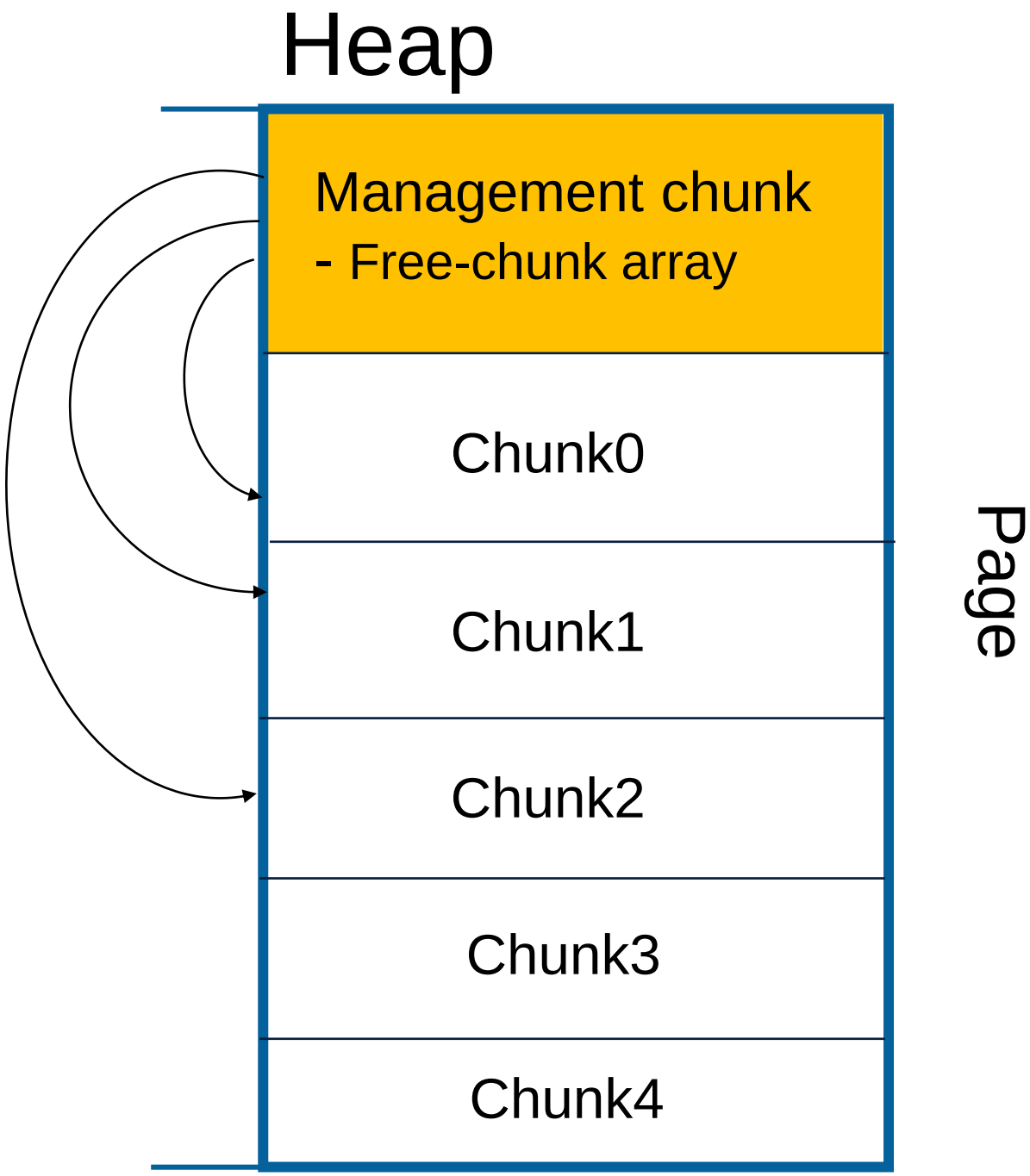
Heap Memory Management

One possibility:

PHP7 – emalloc

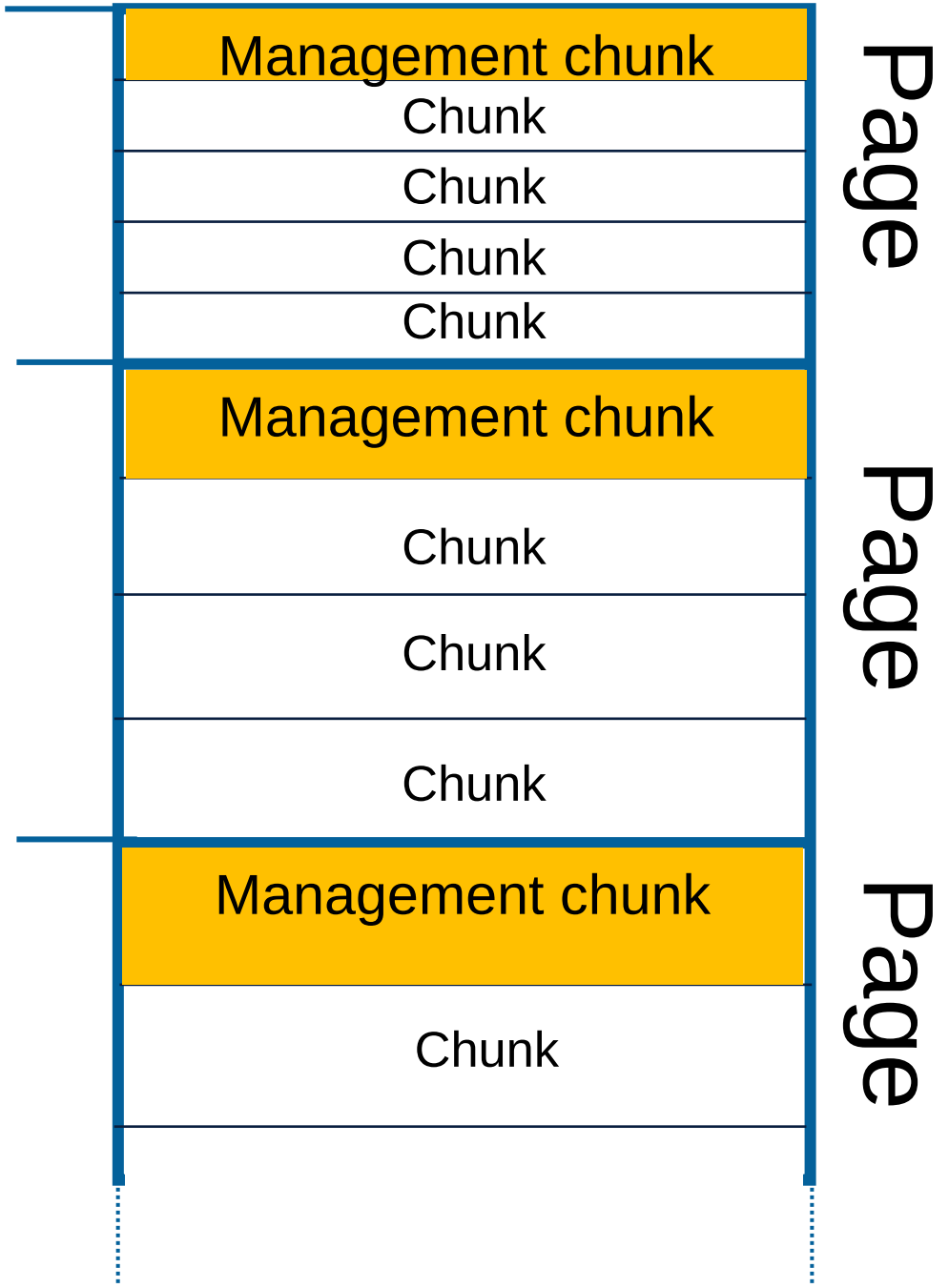
- First chunk has management information
- Management chunk describes other chunks
- Which are free, how big are they etc.

- *(ok, emalloc allocates chunks from the OS, divides them into pages - so the oppositive naming convention. That's a detail).*



Heap Memory Management

Heap could look like this:

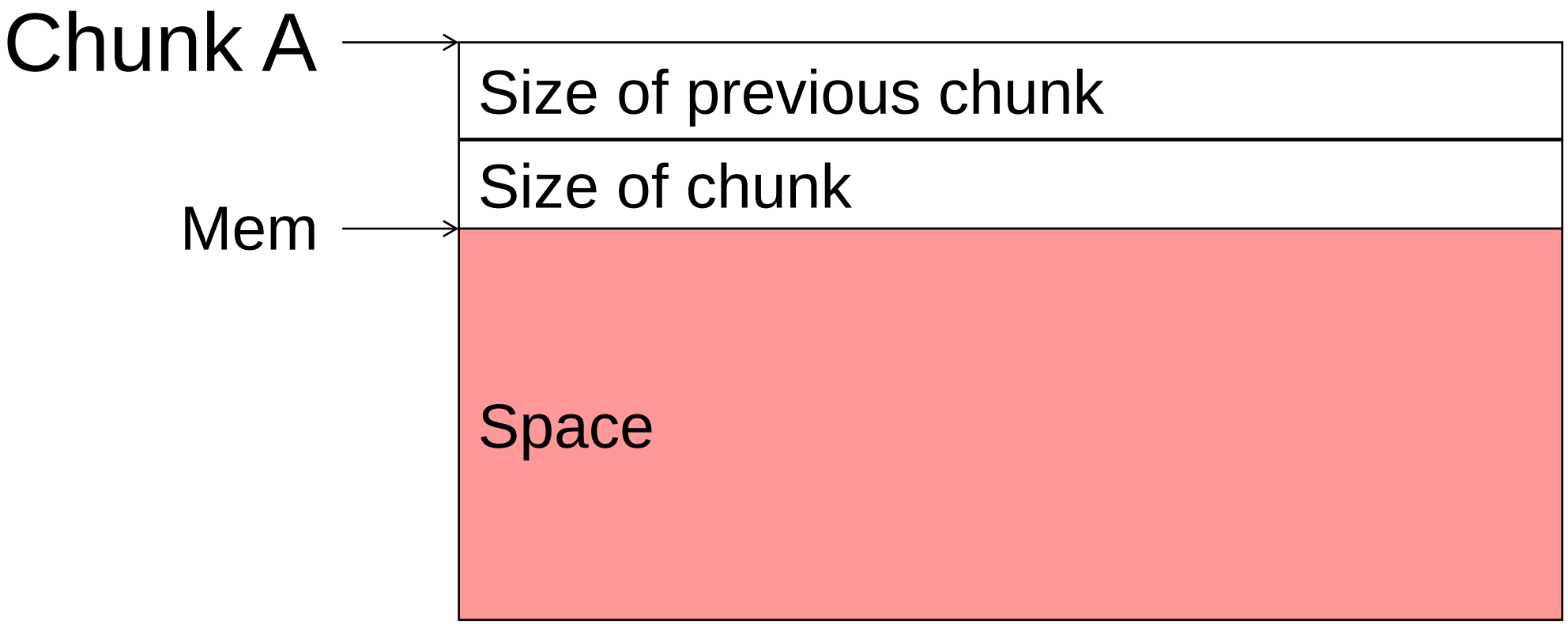


Heap Memory Management

But wait, there’s more!

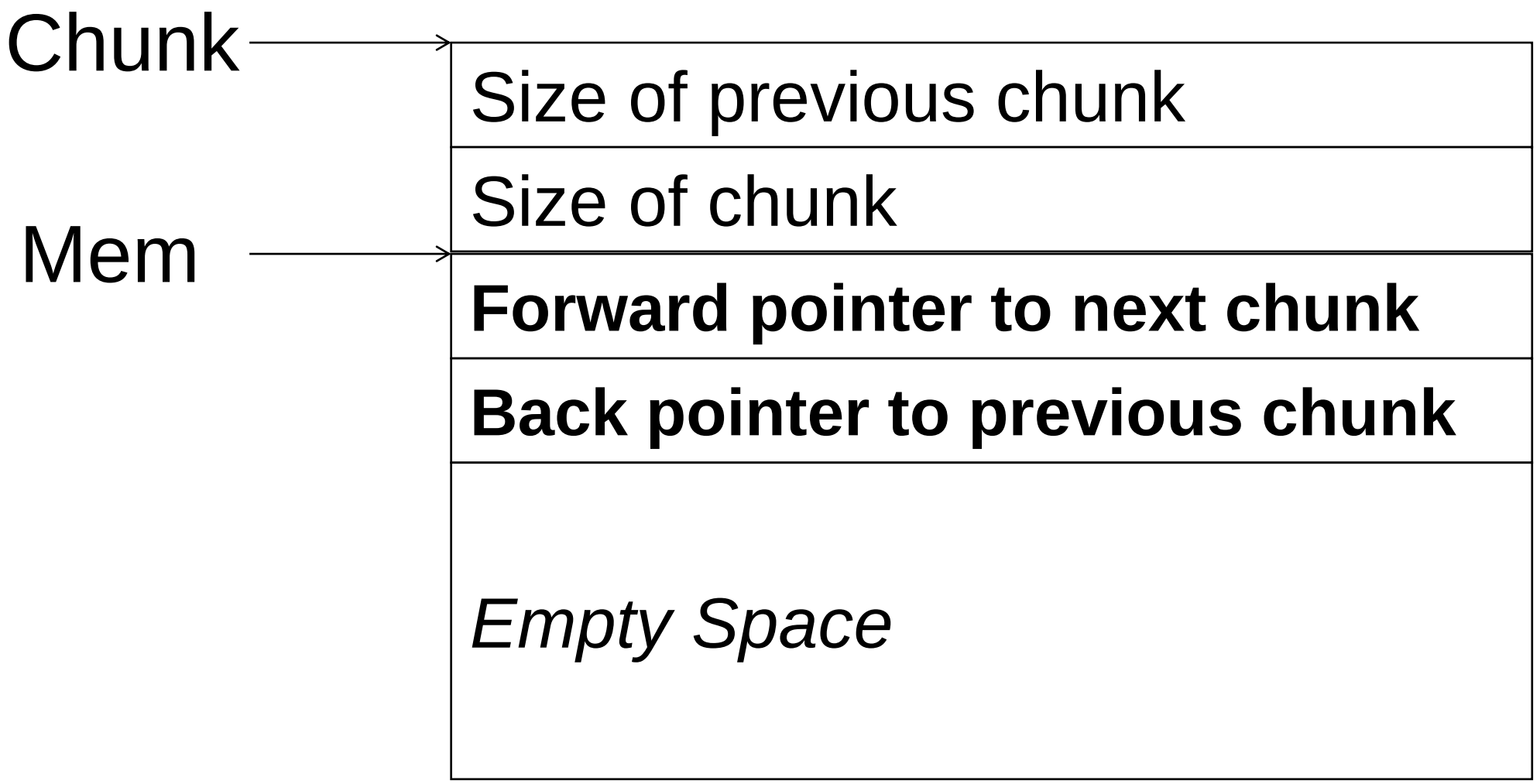
Chunk

Ptmalloc2 **allocated** chunk:



Heap Chunks

Ptmalloc2 **FREE** chunk:

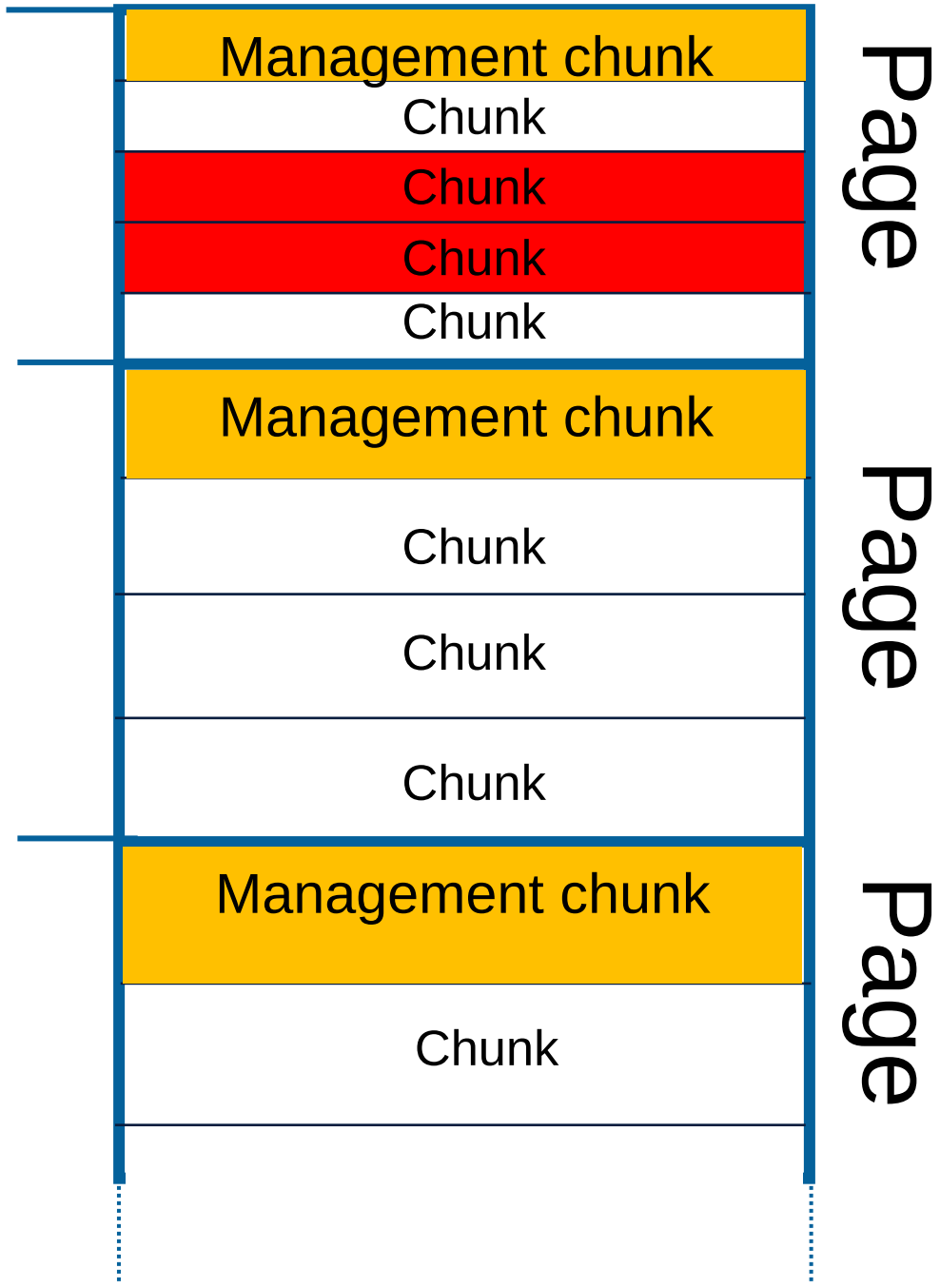


Heap attacks

Heap Attacks: Buffer overflow

Heap attack:

Inter-chunk overflow



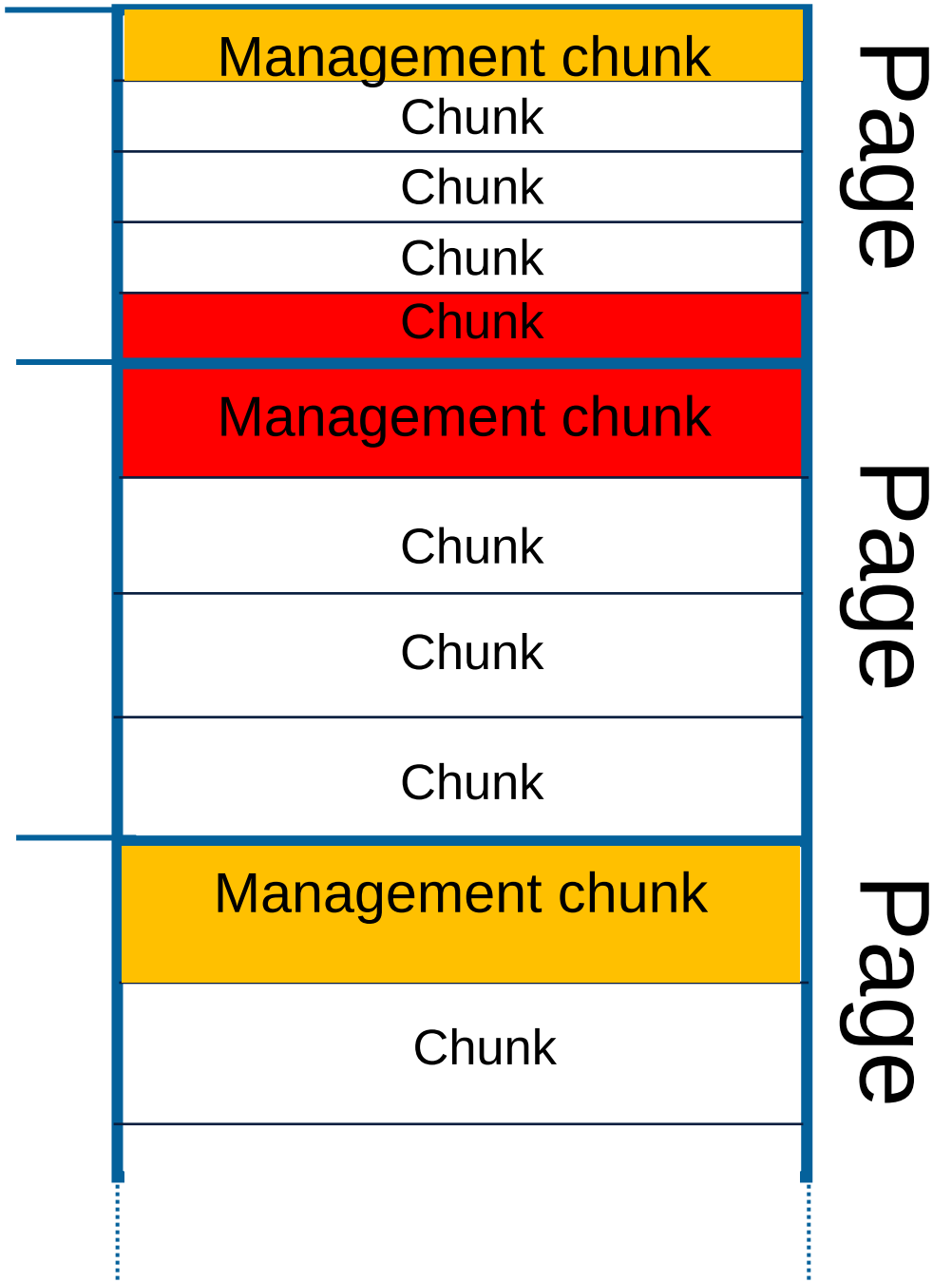
Heap Attacks: Buffer overflow

Heap attack:

Inter-chunk overflow with management chunk

Problem:

- In-band signalling (again)
- Can modify management data of heap allocator
- Therefore, can modify behaviour of heap allocator



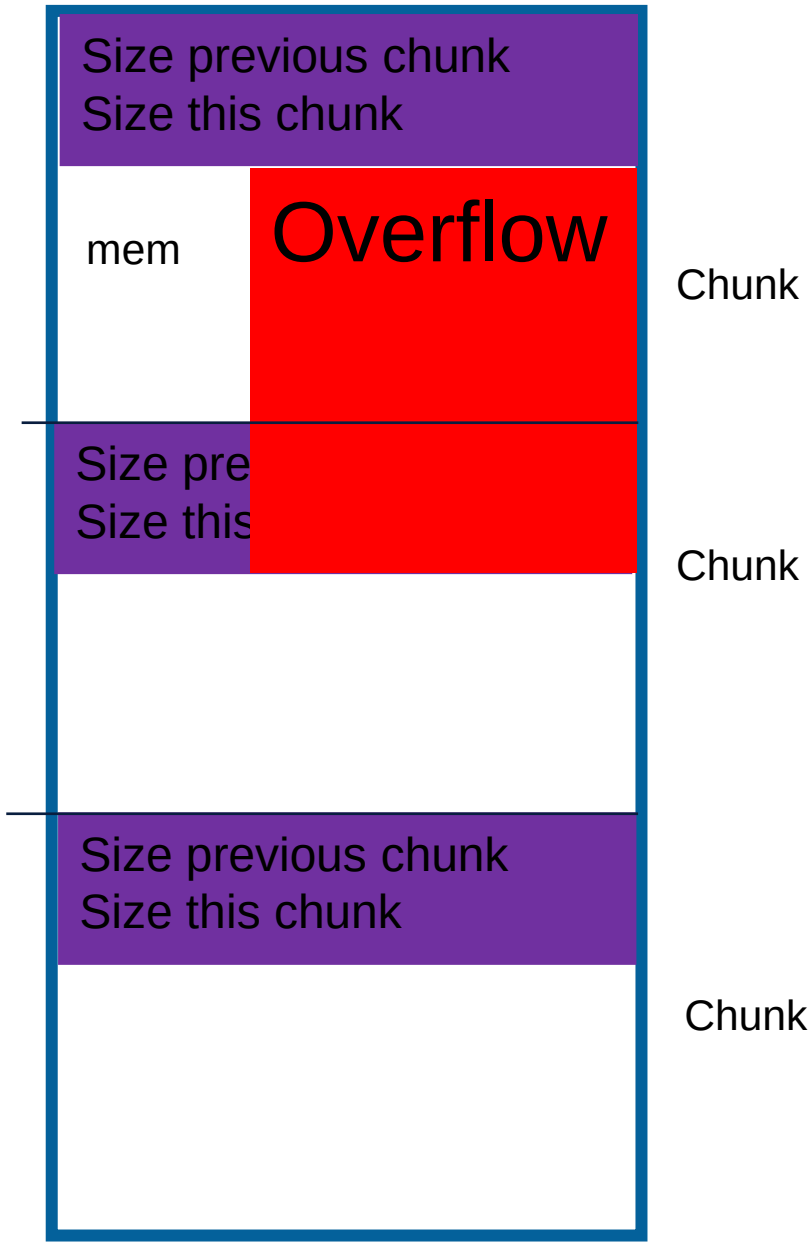
Heap Attacks: Buffer overflow

Heap attack:

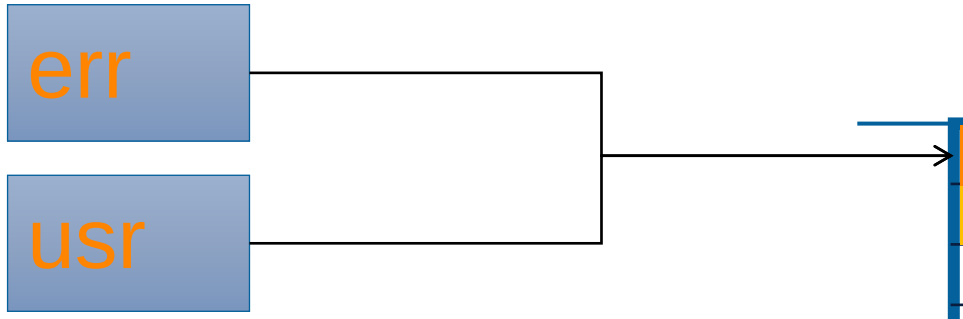
Inter-chunk overflow with chunk metadata

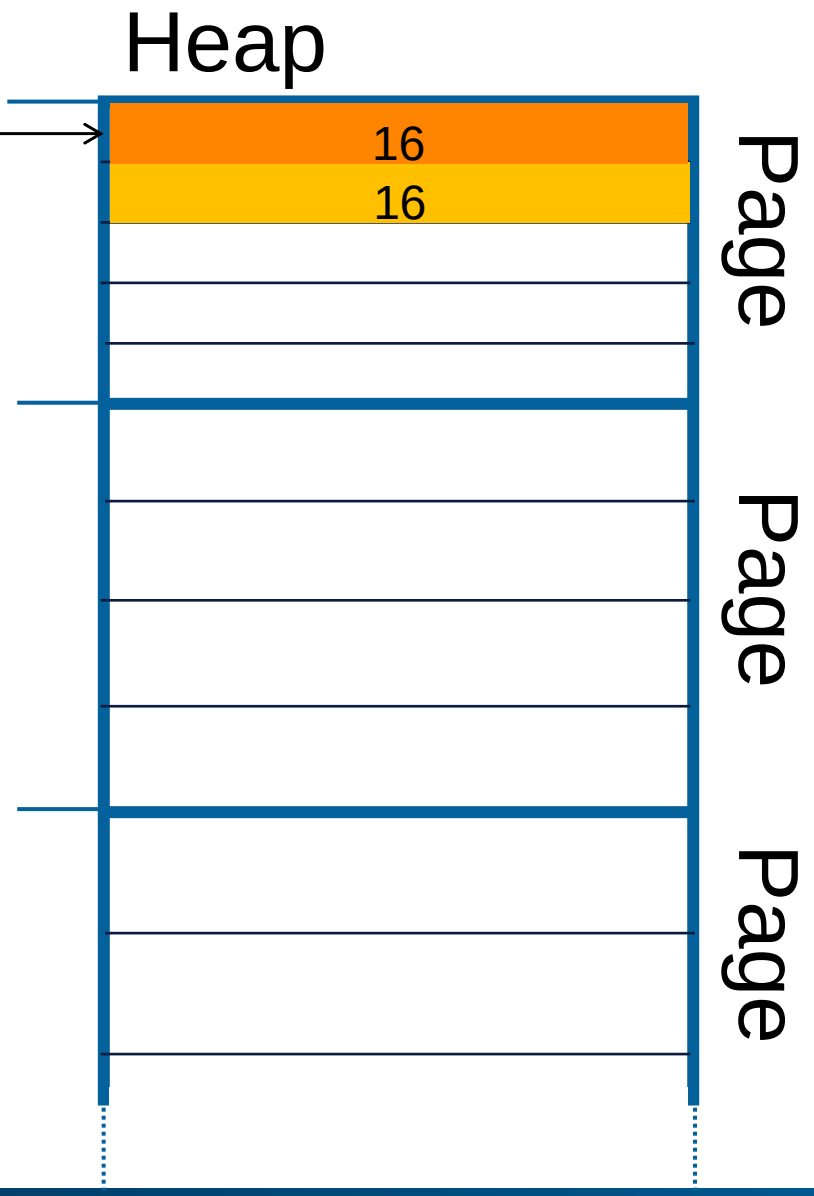
Problem:

- In-band signalling (again)
- Can modify management data of heap allocator
- Therefore, can modify behaviour of heap allocator
  - Create fake chunks
  - Ptmalloc2: Write what where upon free



Heap Attacks: Use after free (UAF)





Use-after-free

```
err = malloc(16)
free(err)

usr = malloc(16);
…
strcpy(usr, “nobody”)
…
strcpy(err, “root err”);
```

Heap Attacks

Recap:

- A buffer overflow on the heap can modify other buffers on the heap
- A buffer overflow on the heap can influence memory allocator management data structures (junks etc.)

References

Resources:

- http://homes.soic.indiana.edu/yh33/Teaching/I433-2016/lec13-HeapAttacks.pdf
- http://www.pwntester.com/blog/2014/03/23/codegate-2k14-4stone-pwnable-300-write-up/