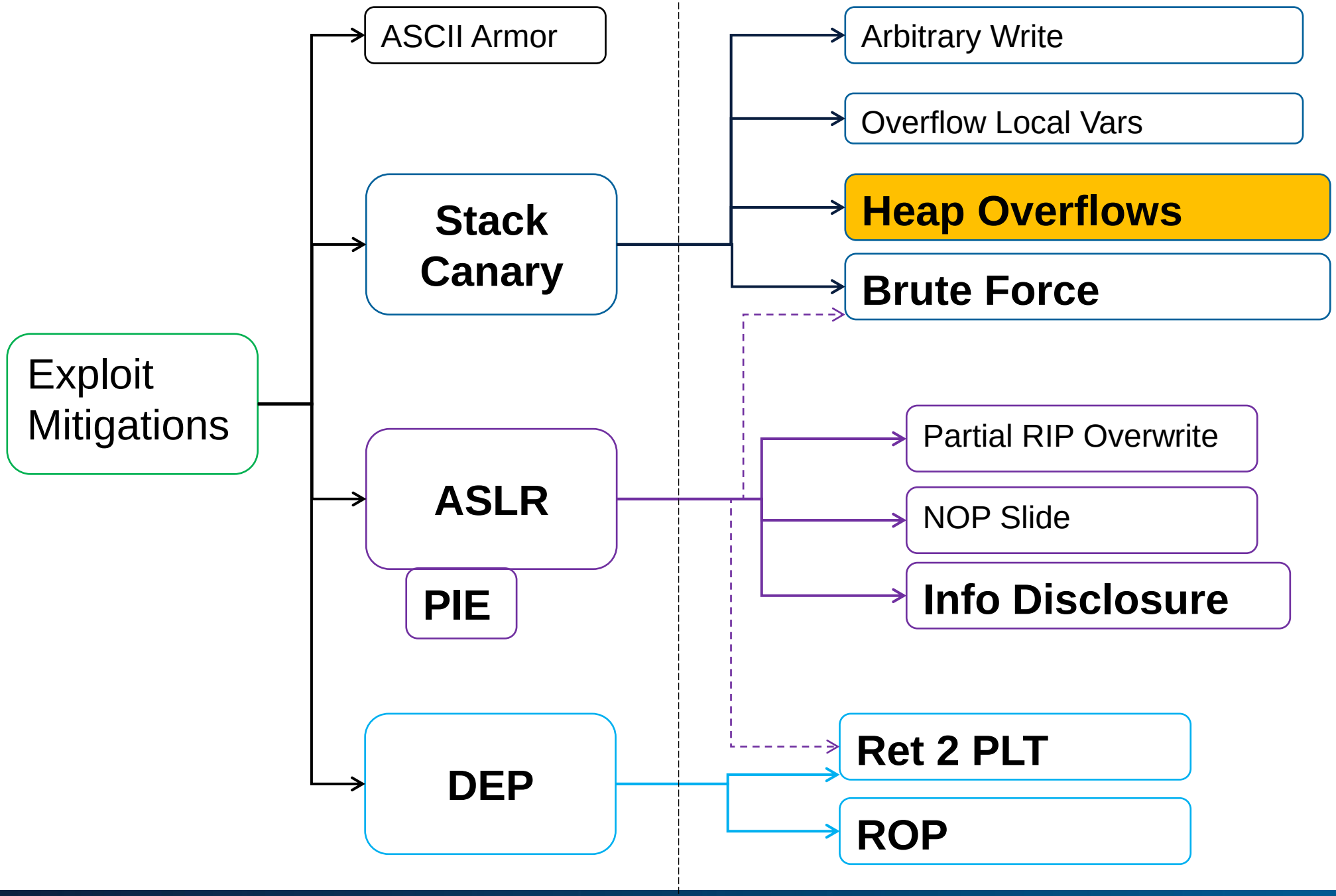
Defeat Exploit Mitigation

Heap Intro


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

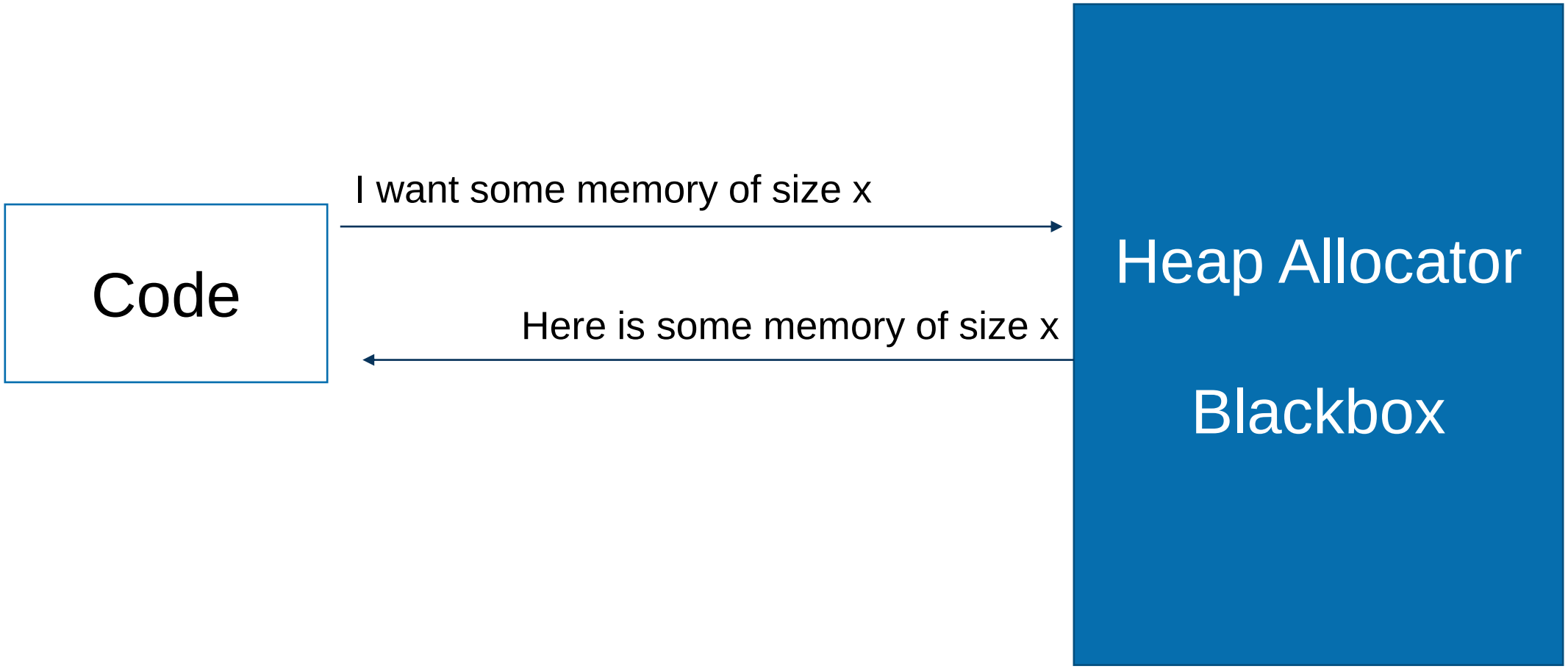
Heap:

- 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



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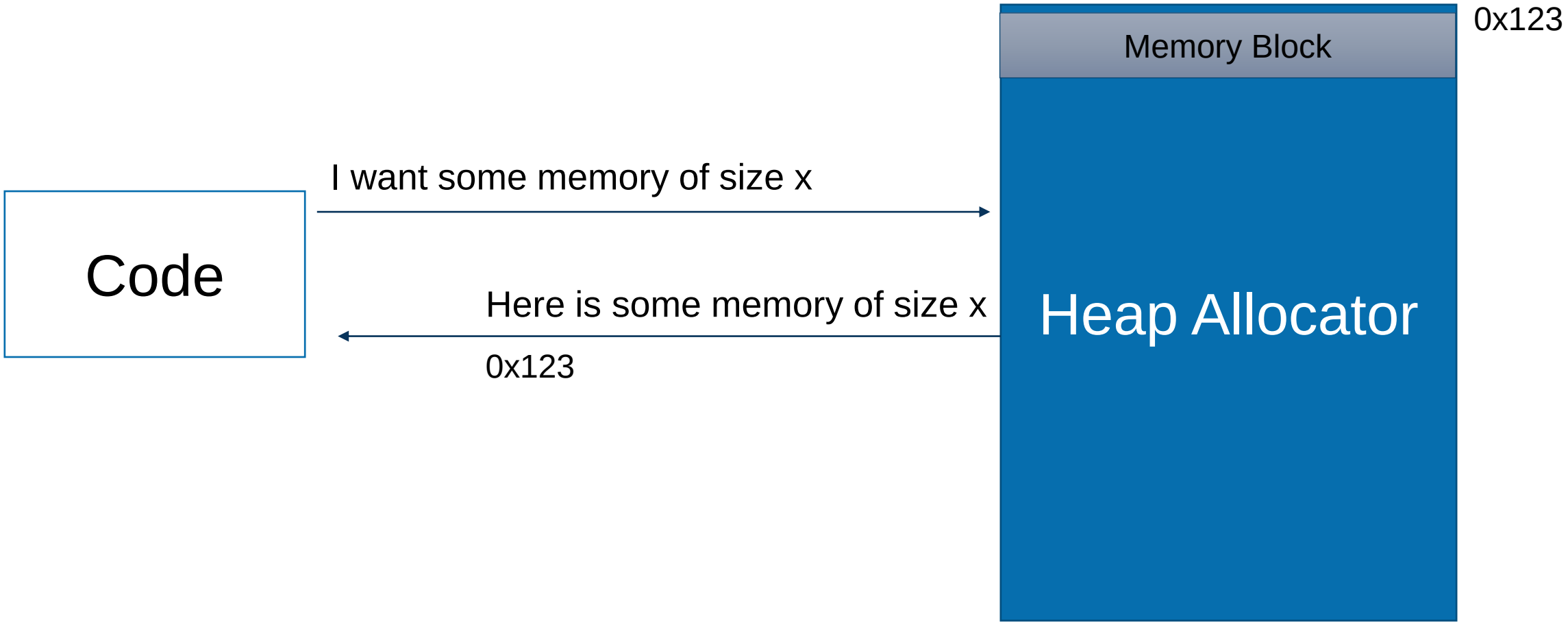
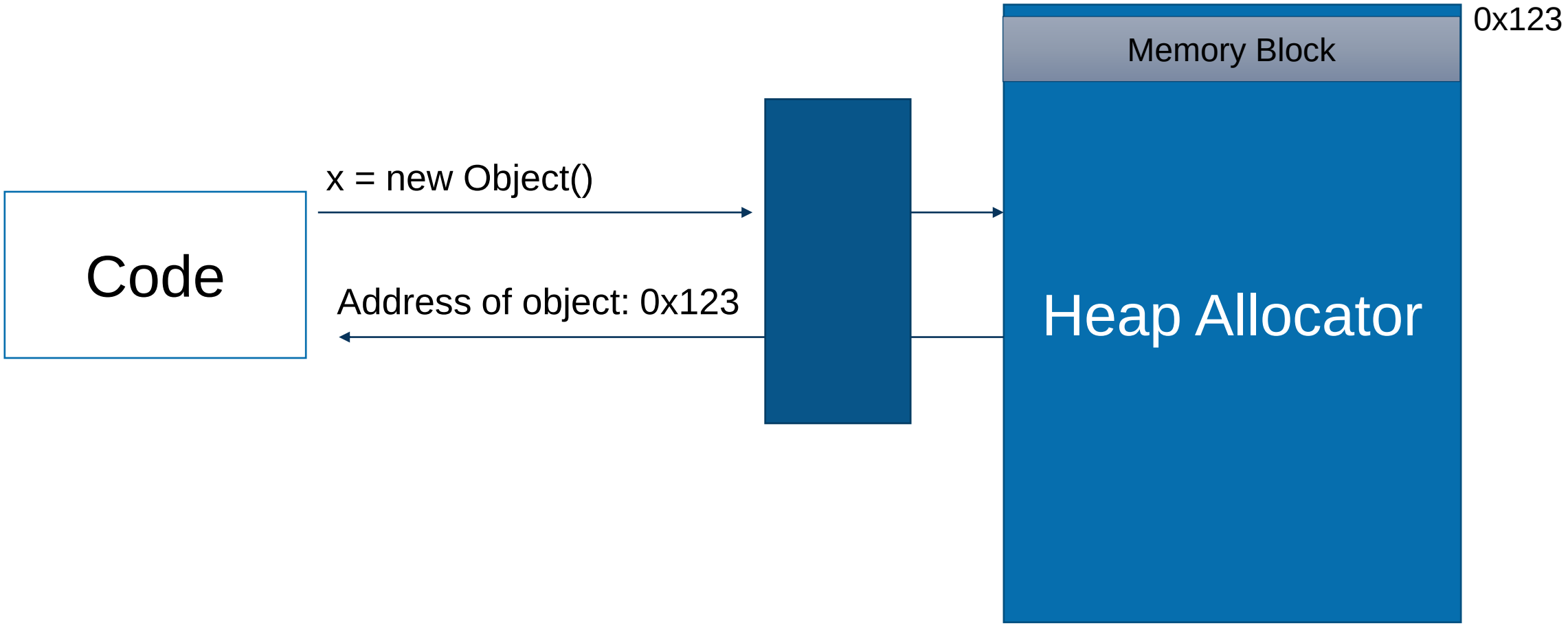


Heap Introduction



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)

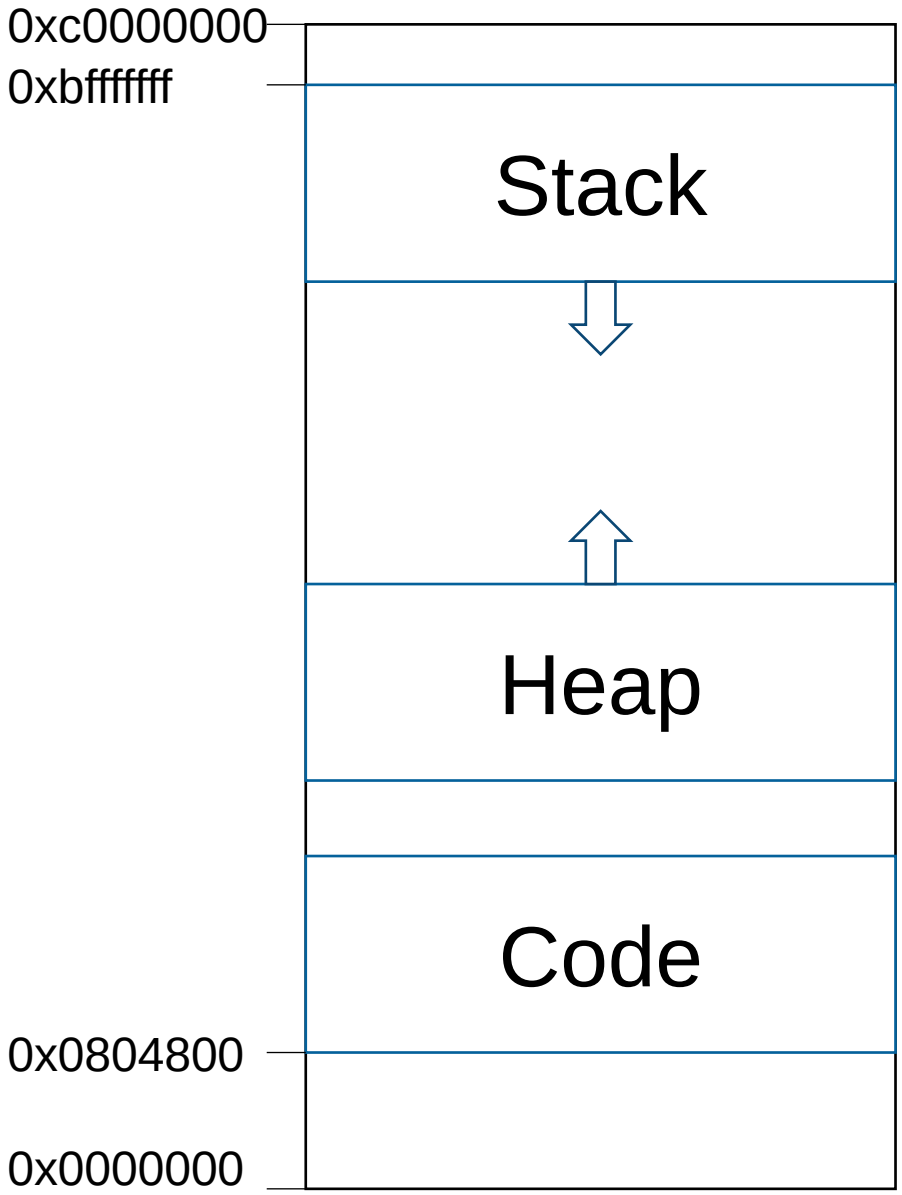
- Allocated “len” size memory block
- Returns a pointer to this memory block

free(ptr)

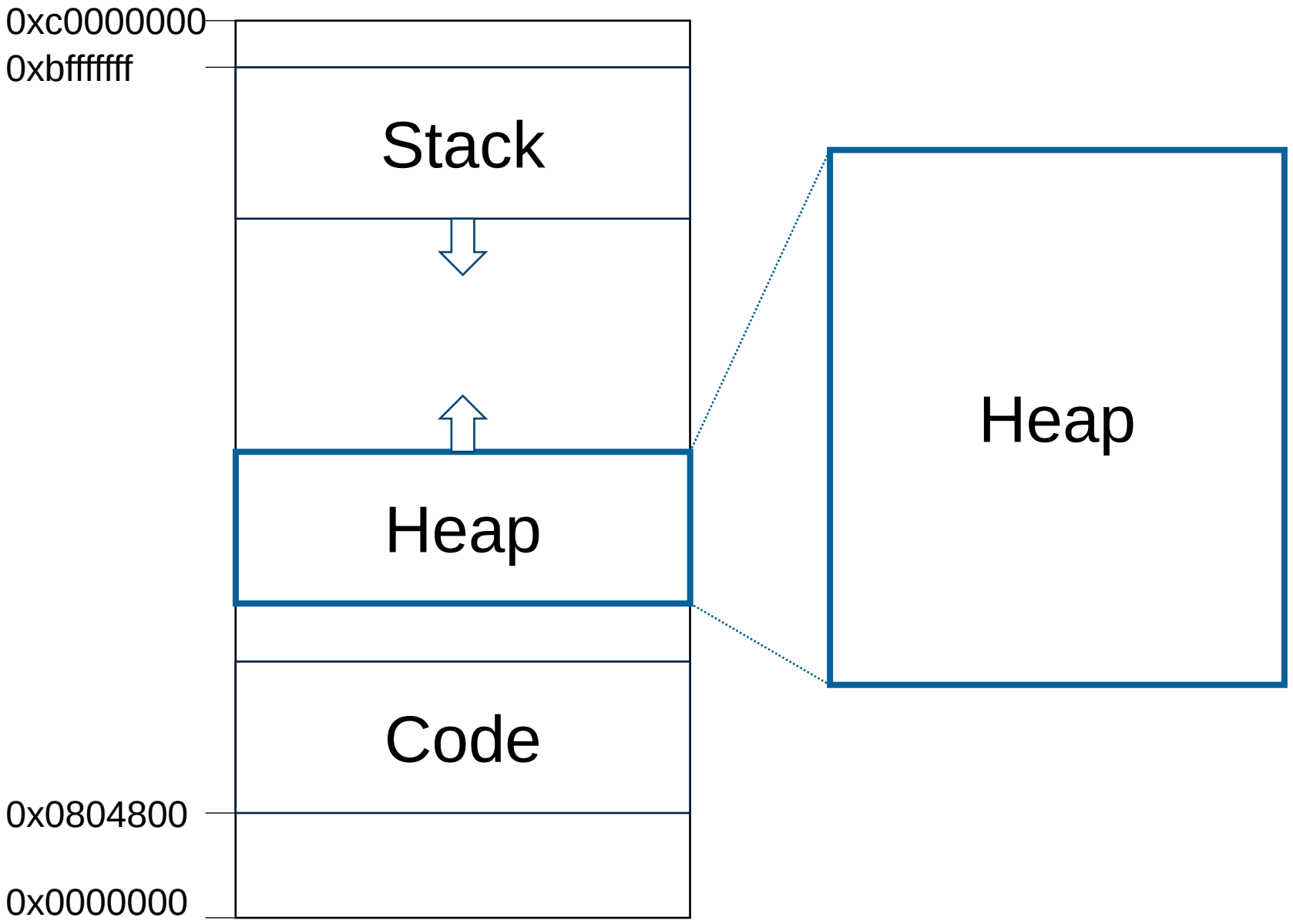
- Tells the memory allocator that the memory block can now be re-used
- Note: ptr is NOT NULL after a free()

Heap – Simplified

Heap: Memory Layout



Heap: Memory Layout



Heap

What is a heap allocator doing?

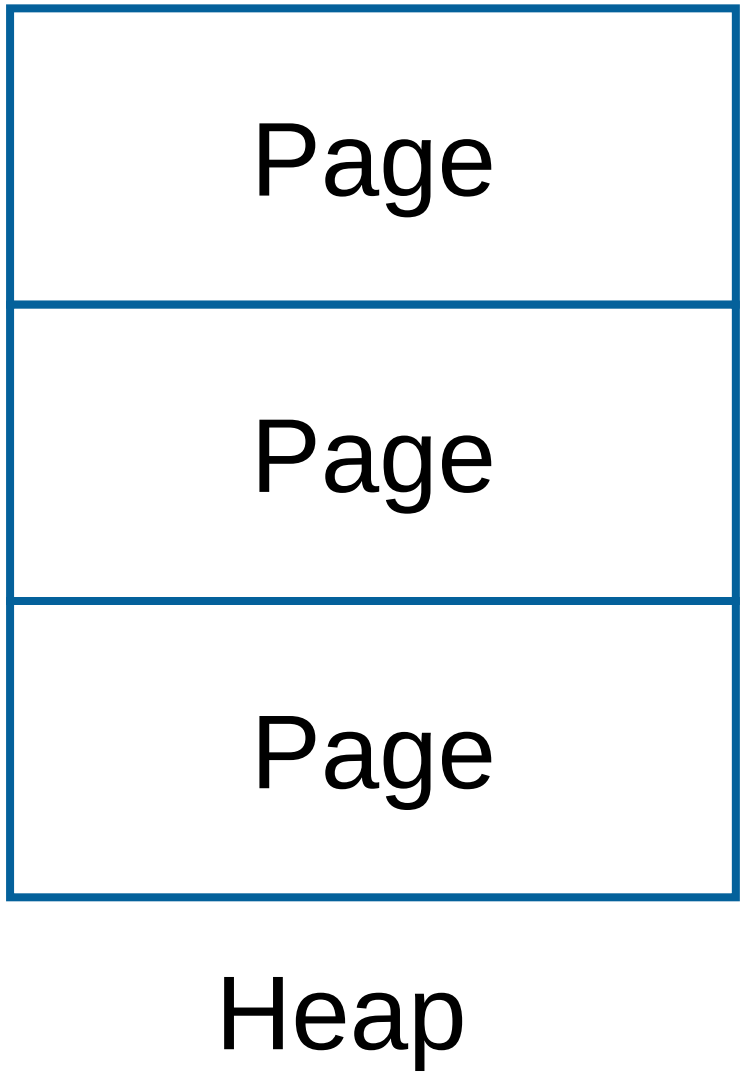
- Allocate big memory **pages** from the OS
- Manage this **pages**

- Split the **pages** into smaller **bin's**
- each **bin** contain **chunks** of a specific size
- Make these **chunks** available to the program

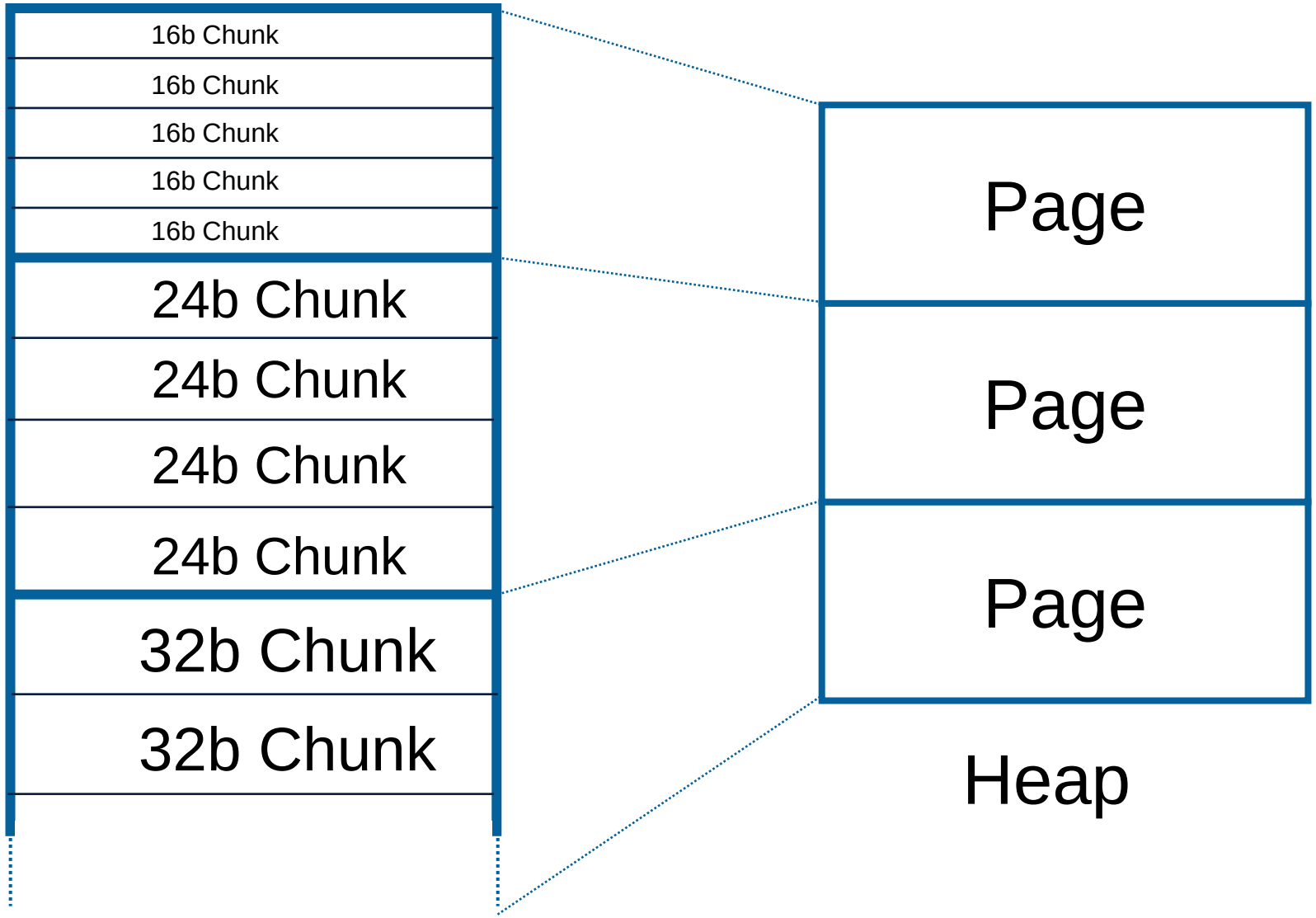
Heap: Memory Layout

Page:

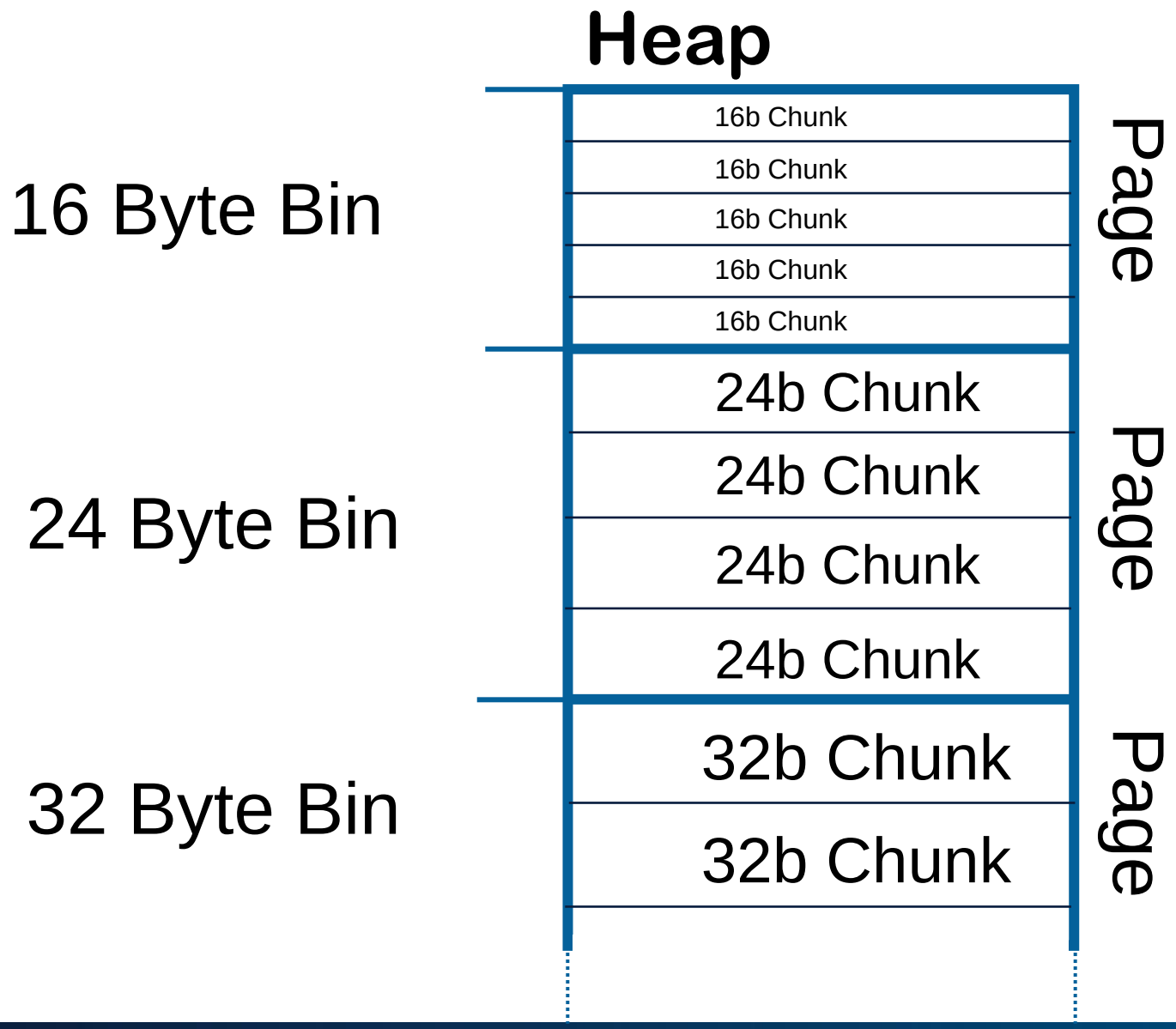
- A memory page
- Usually **4k**
  - (Can also be 2 Megabytes or other, special)
- Allocated via sbrk() or mmap()
  - libc call which does a syscall to ask the OS for more "RAM"



Heap: Memory Layout



Heap: Oversimplified example



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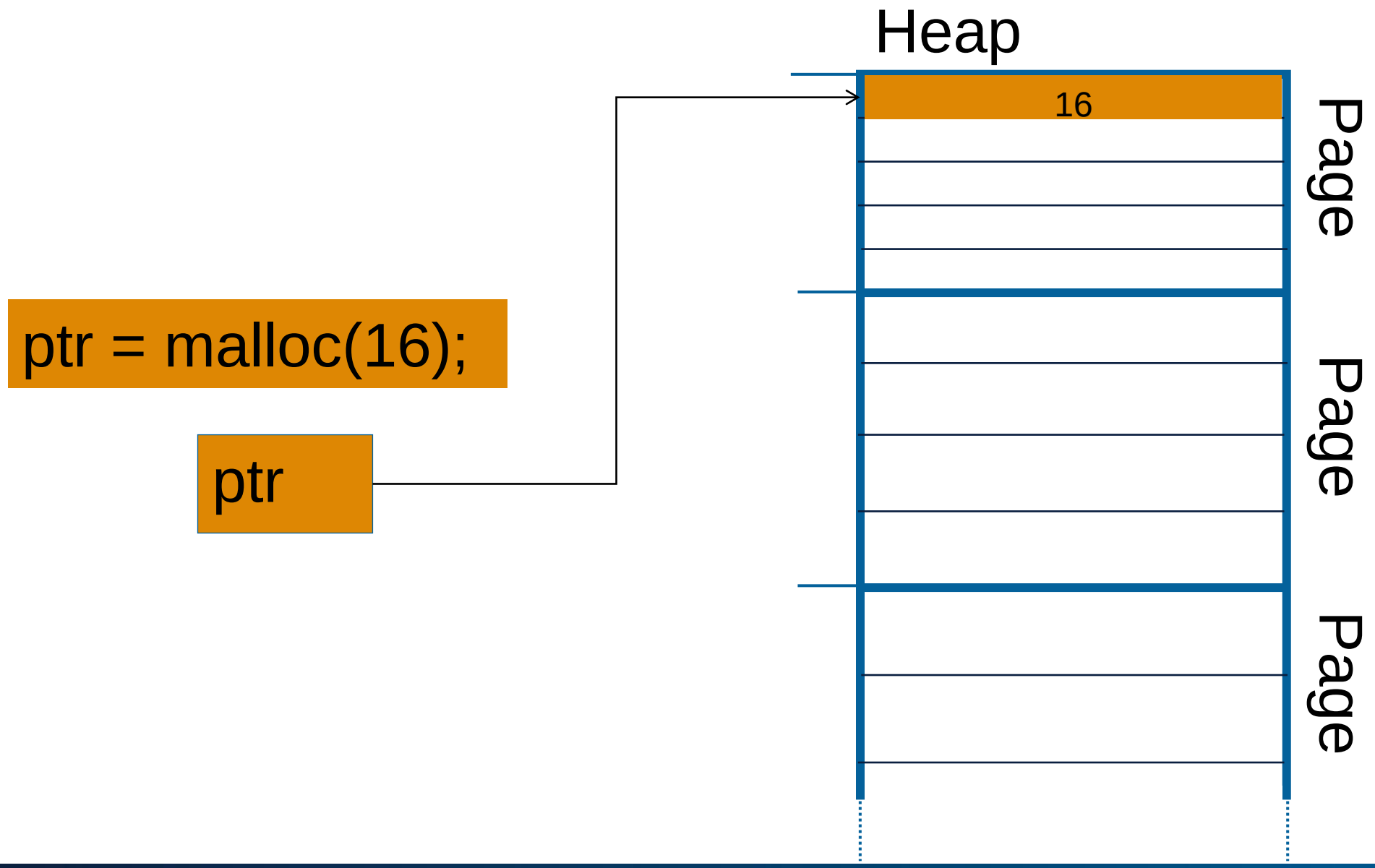

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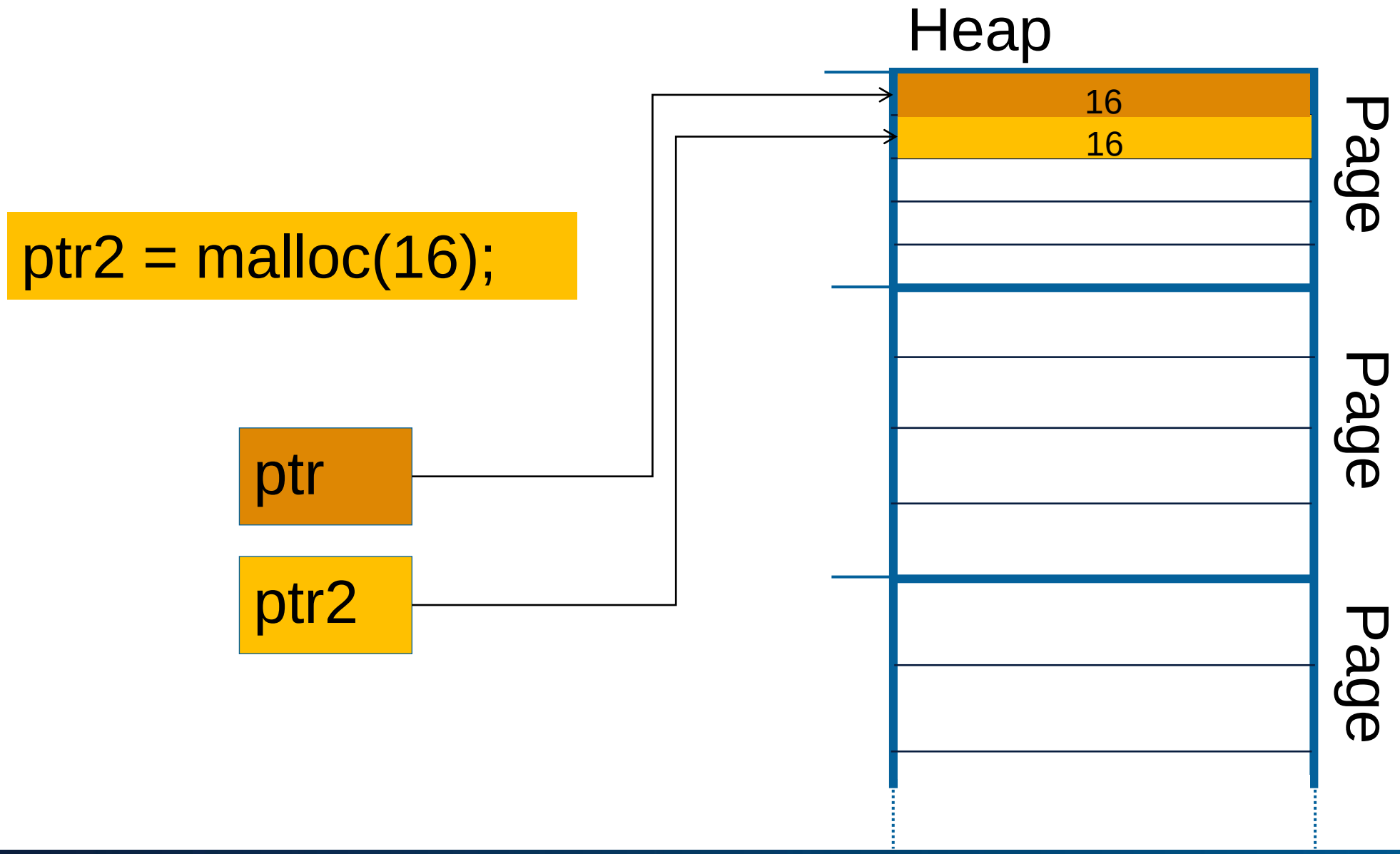

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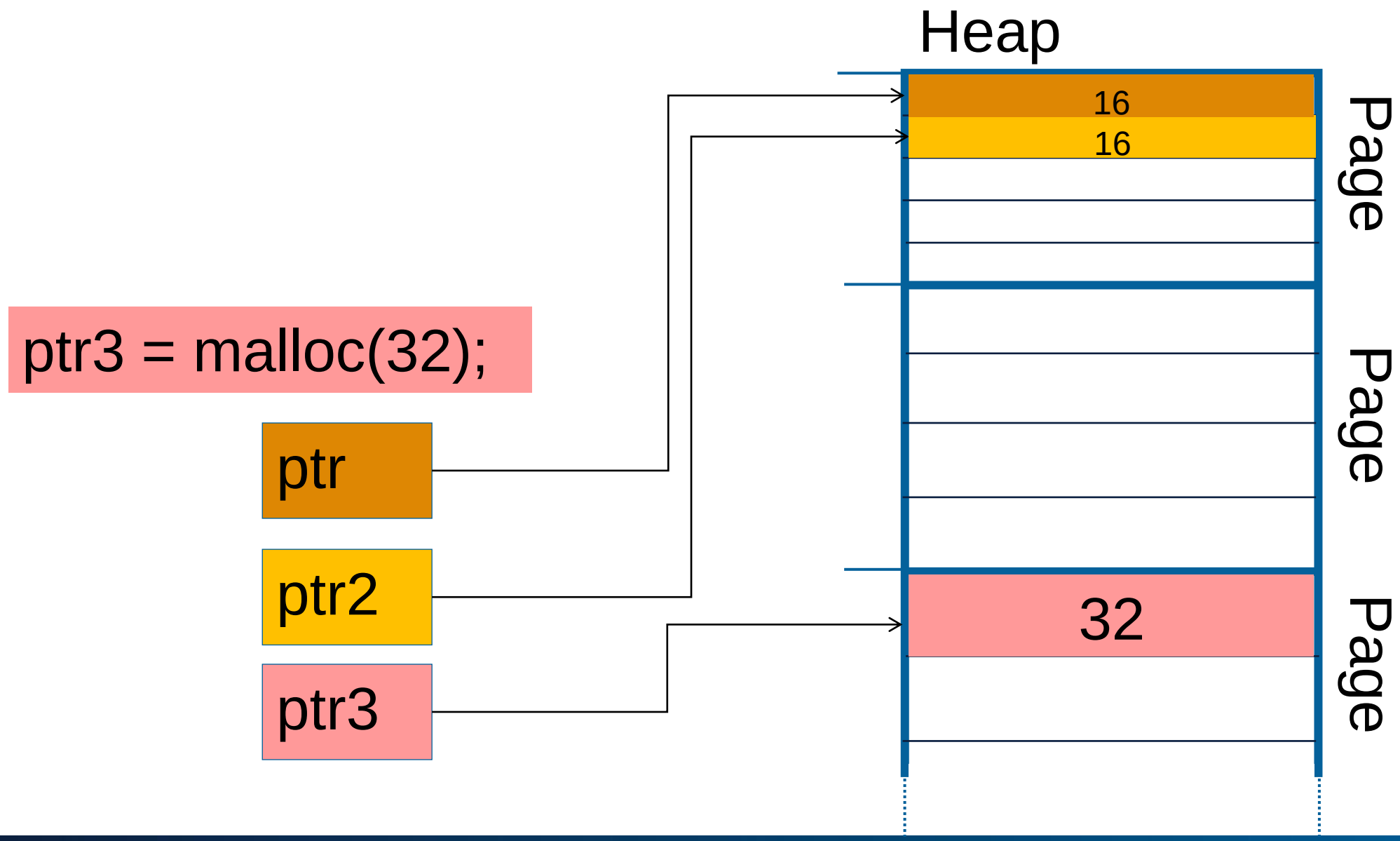

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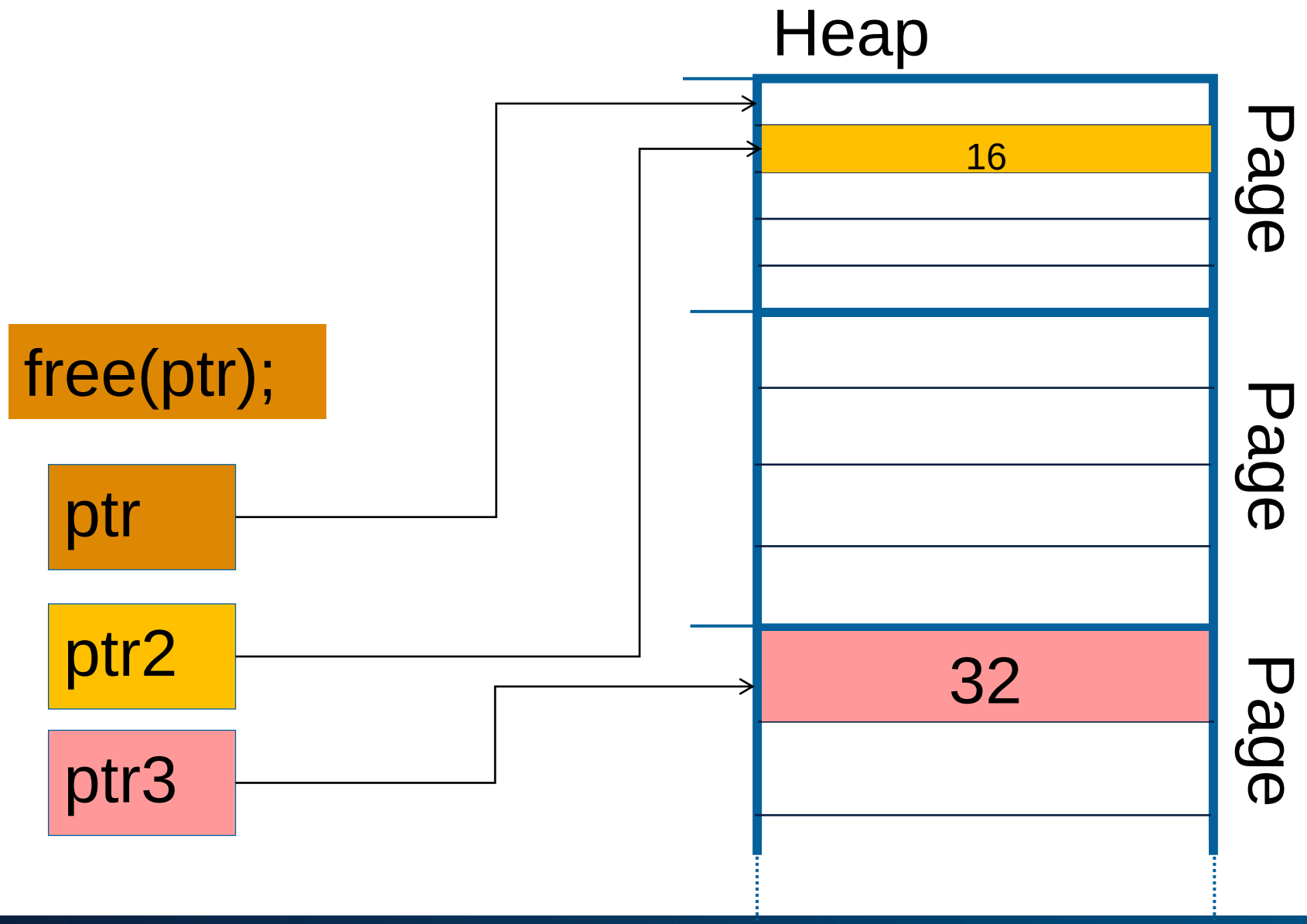

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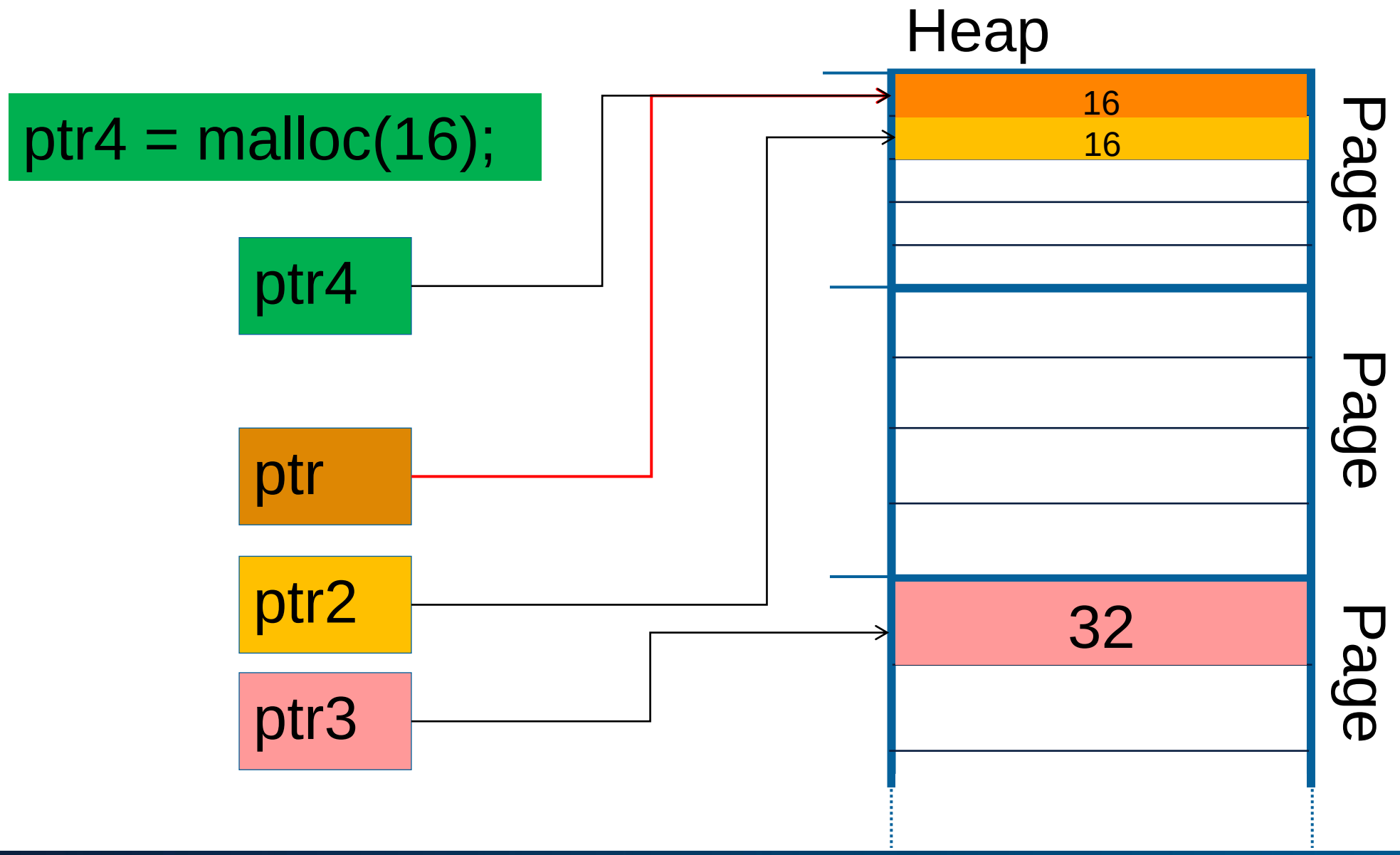
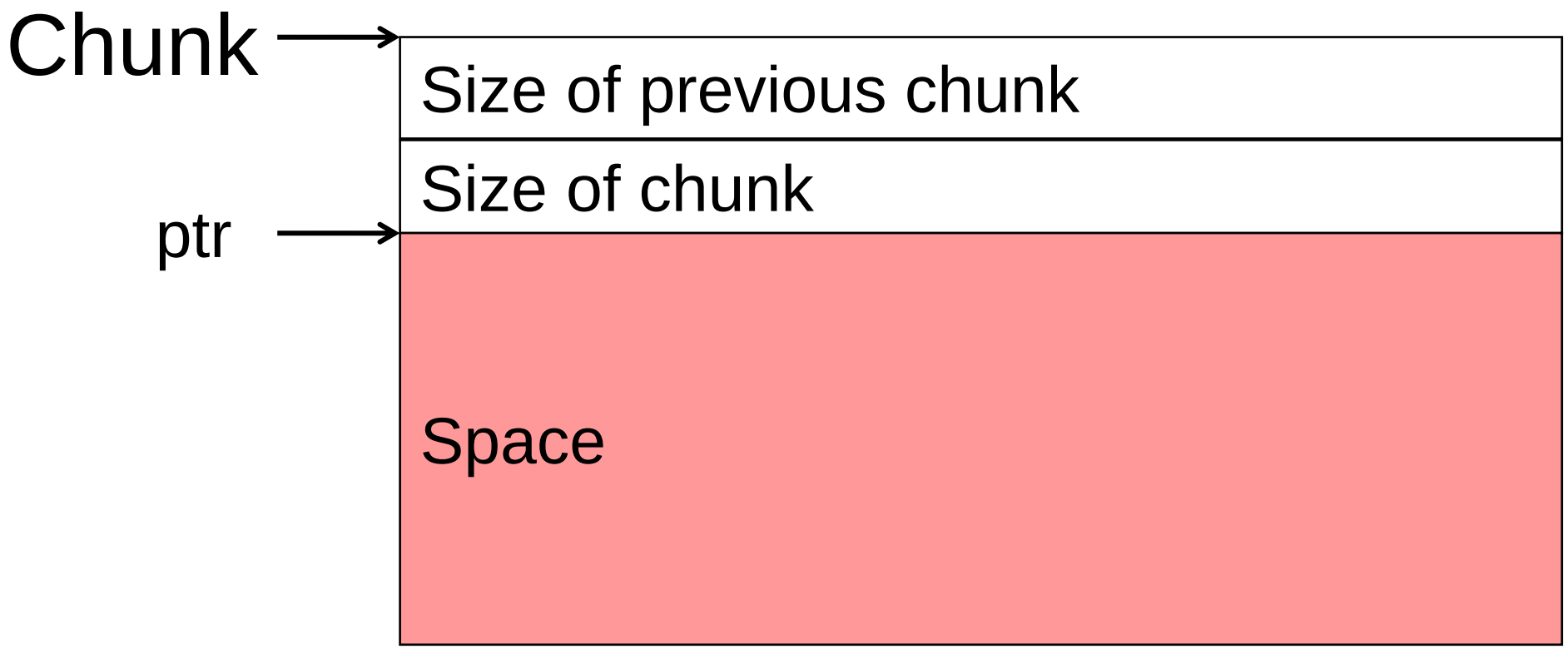


Heap Interface



Heap - Recap

Recap:

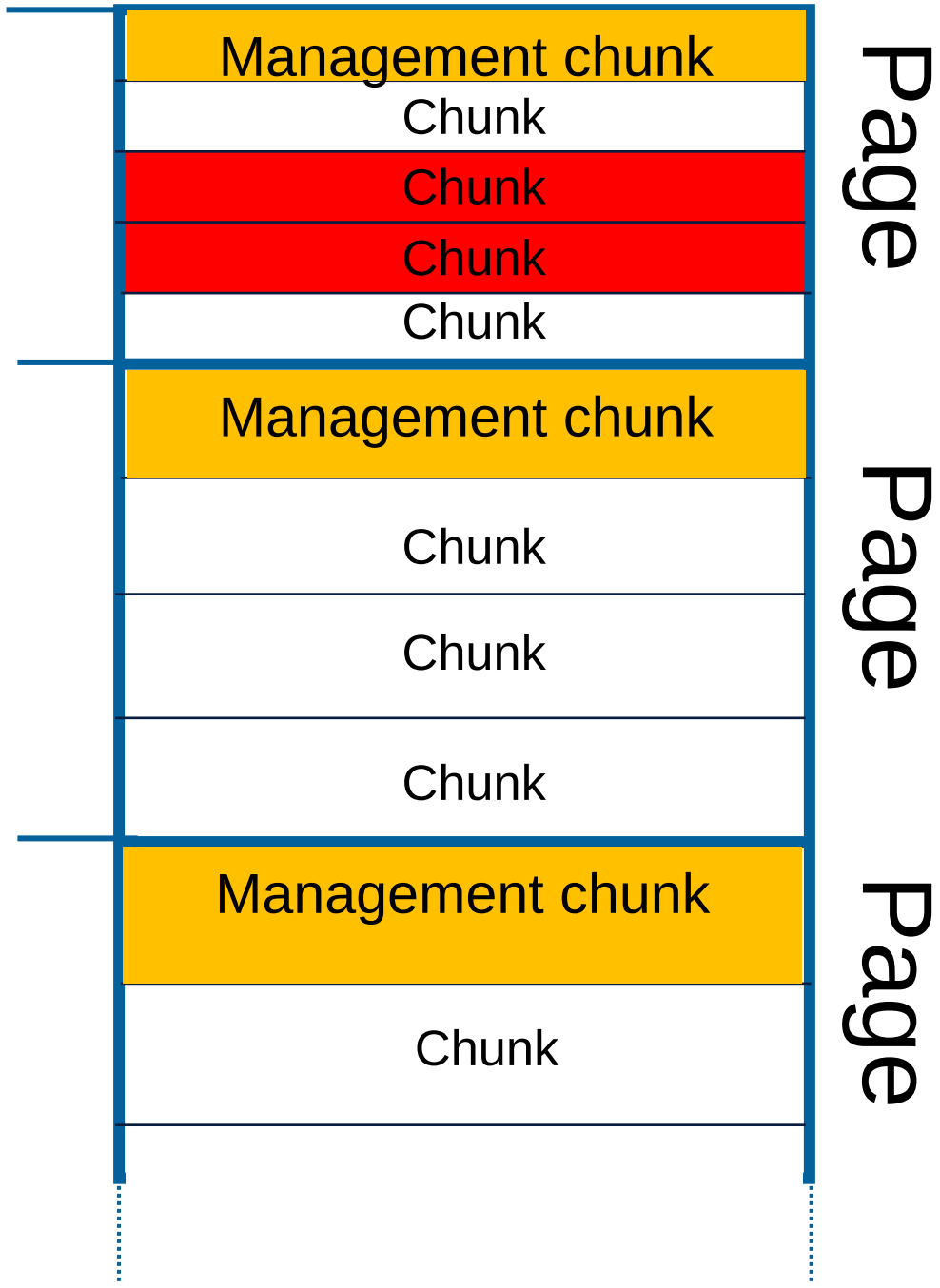
- Heap divides big (4k) memory **pages** into smaller **chunks**
- Heap gives these **chunks** to the program on request
- A **pointer** to a heap allocation points to the **data** part of the **chunk**

Heap attacks

Heap Attacks: Buffer overflow

Heap attack:

Inter-chunk overflow



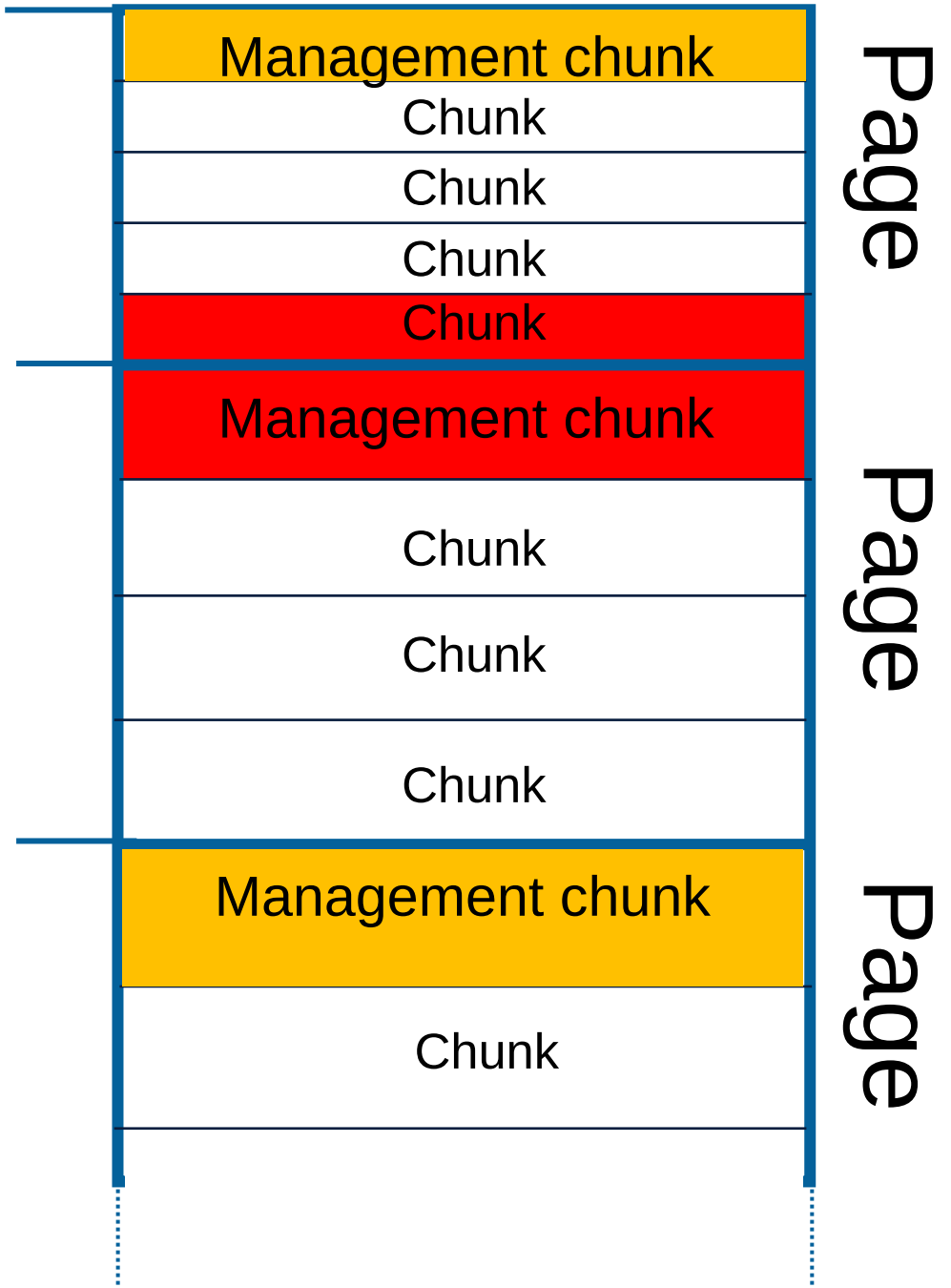
Heap Attacks: Buffer overflow

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



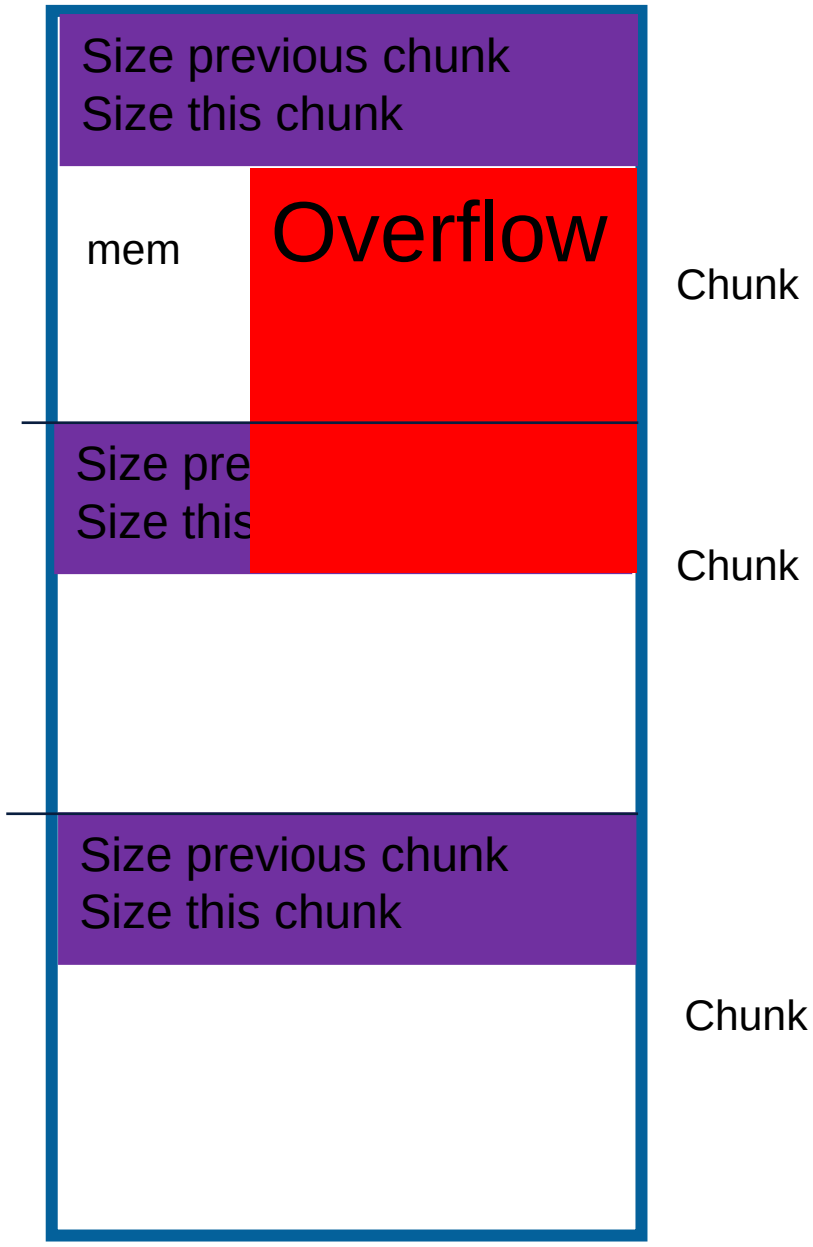
Heap Attacks: Buffer overflow

Heap attack:

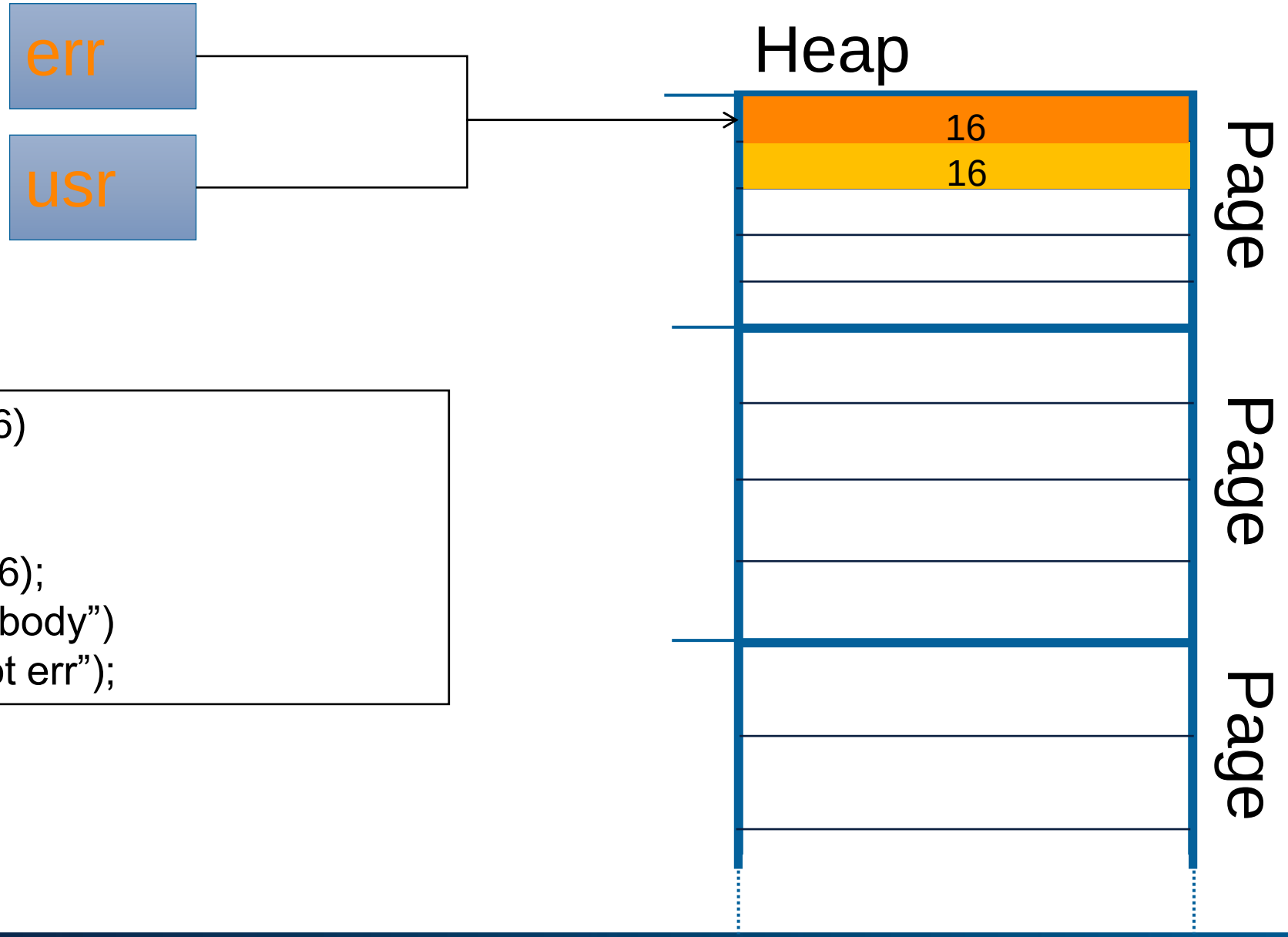
Inter-chunk overflow with chunk metadata

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)




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

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

Heap Attacks:
Use After Free (UAF)

Heap Attack: UAF

UAF:

```
Use after free
```

Or more correctly:

```
Use an object, after the memory it has been pointing to has been freed,
and now a different object is stored at that location
```

Heap Attack: UAF

So, what is UAF?

- We have a pointer (of type A) to an **object**
- The **object** get's **free**()'d
  - This means that the memory allocater marks the object as free
  - The object will not be modified!
  - (Similar to deleting a file on the harddisk)
  - The pointer is still valid
- **Another object** of type B (of similar size) get's **allocated**
- Memory allocator returns the previously free'd object memory space

- Attacker has now **a pointer (type A) to another object (type B)**!
- This object can be modified
  - Depending on the types A and B

Object Oriented Languages

Dobin: *“OO ist just some fancy C structs with function pointers”*

OO in C:

```
typedef struct animal {
        int (*constructor)(void *self);
        int (*write)(void *self, void *buff);
        void *data;
} AnimalClass;

AnimalClass animal;
animal.constructor = &constructor;
animal.data = malloc(…);
…
animal.constructor(&animal);
```

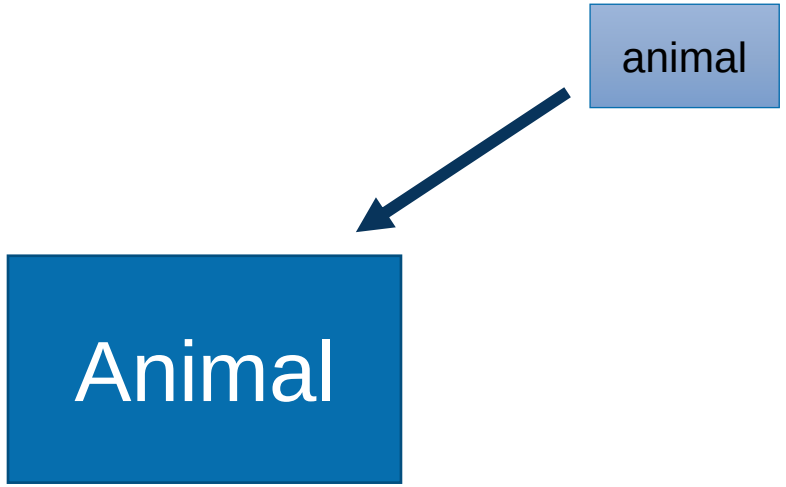
Garbage Collection

Dobin: *“Garbage collection is just fancy structs with reference counter”*

```
typedef struct animal {
        int (*constructor)(void *self);
        int (*write)(void *self, void *buff);
        void *data;
        int refCount;
} AnimalClass;

AnimalClass animal;
animal.refCount = 0;
…
Animal animal2 = &animal;
Animal.refCount++;
```

Use After Free

```
animal = new Animal()
if error:
  free(animal)

car = new Car()
car.drive(100000000)

animal.eat()
```



Animal Class	Animal Object
int hungry	0
int tired	5
func eat()	0x123
func walk()	0x512

Car Class	Car Object
int doors	4
int locked	0
int fuel	10
func drive()	0xabc

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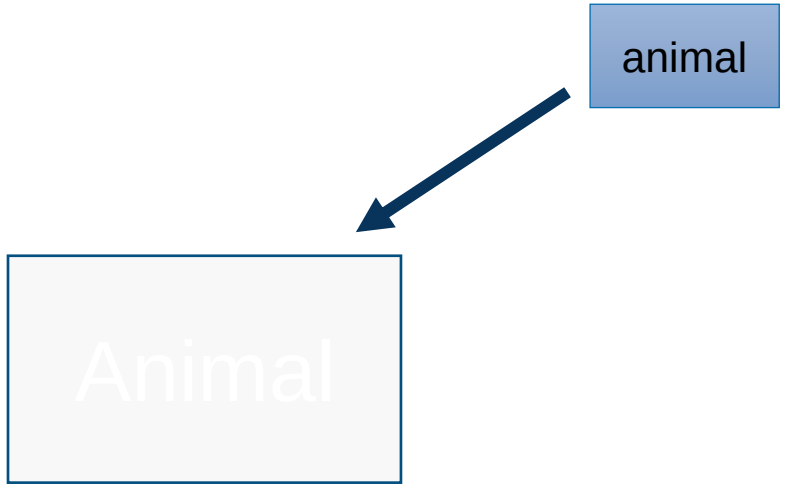

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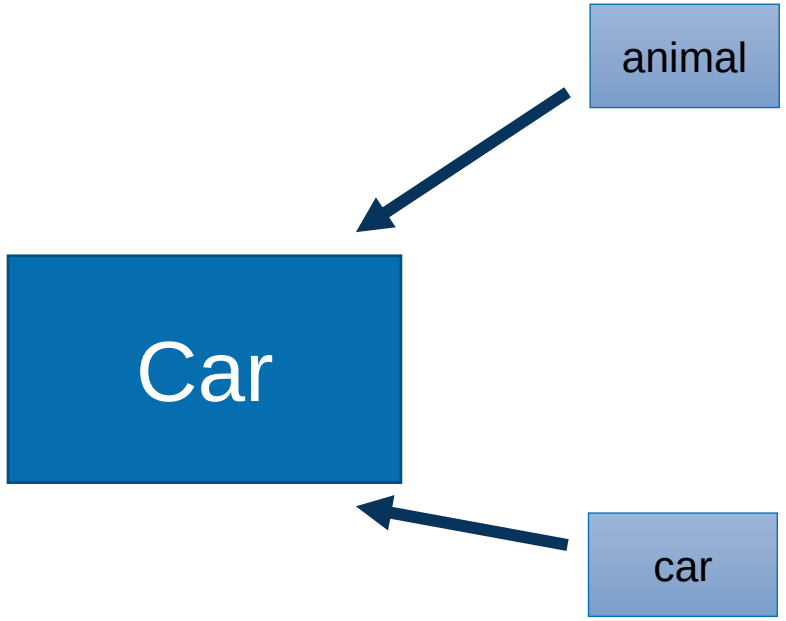

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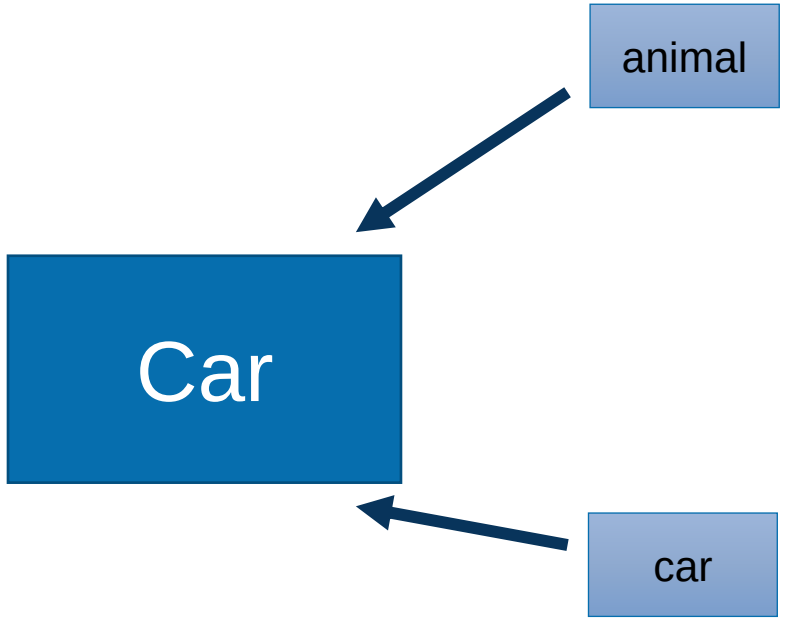
Use After Free

```
Car::drive(distance):
  car.fuel = car.fuel - distance

animal = new Animal()
if error:
  free(animal)

car = new Car()
car.drive(100000000)

animal.eat()
```

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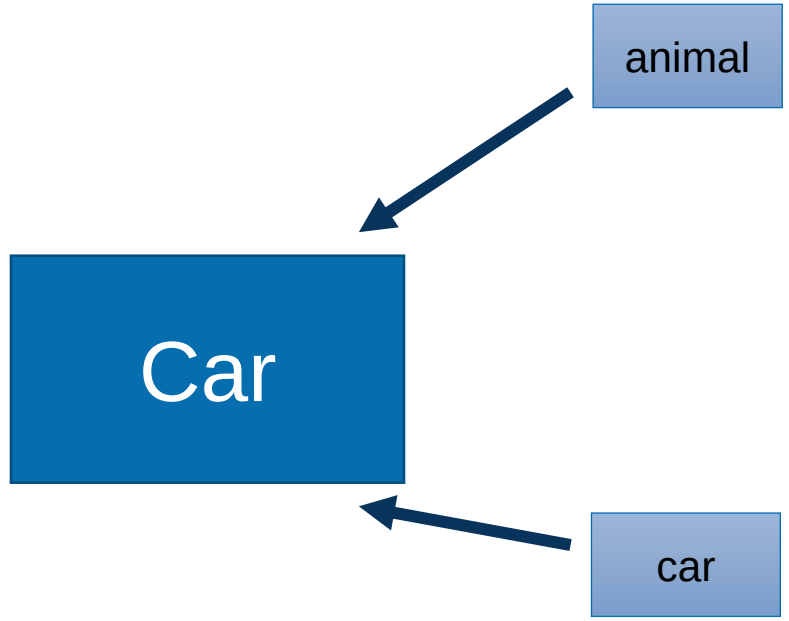


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Car::drive(distance):
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Animal Class	Animal Object
int hungry	0
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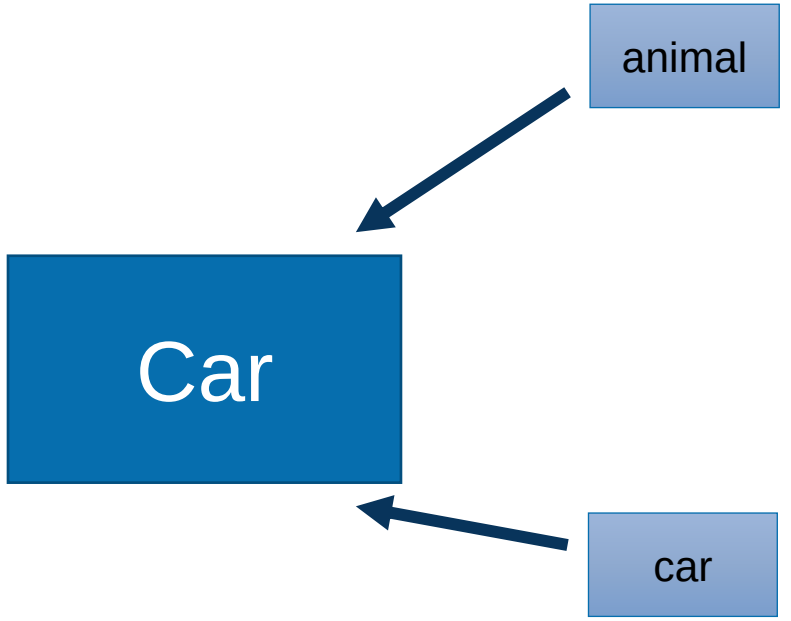


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Challenge 33 UaF

Mongoose Web Server

- /login
- /logout
- /ping?asdf

Challenge 33 UaF

```
// An authenticated user
struct t_authenticated {
    int role;
    char sessionid[128];
    void (*logout_handler)();
};

// Only supports 1 authenticated user for now
struct t_authenticated *Authenticated;
```

+0	int role
+8	char sessionid[128]
+136	(*logout_handler)()

Challenge 33 UaF

```
// REST: /login
void rest_login(struct mg_connection *c, struct http_message *hm) {
    char response[RESPONSE_LEN];

    // Malloc and init for Authenticated struct
    Authenticated = malloc(sizeof(struct t_authenticated));
    Authenticated->logout_handler = &logout_handler;
    Authenticated->role = 23;
    strcpy(Authenticated->sessionid, "5"); // chosen by a fair dice roll

    strncpy(response, Authenticated->sessionid, 8);
    mg_send_head(c, 200, RESPONSE_LEN, "Content-Type: text/plain");
    mg_send(c, response, RESPONSE_LEN);
}
```

Challenge 33 UaF

```
// REST: /logout
void rest_logout(struct mg_connection *c, struct http_message *hm) {
    char response[512];

    // Send answer
    sprintf(response, "Logout %i\r\n", Authenticated->role);
    mg_send_head(c, 200, strlen(response), "Content-Type: text/plain");
    mg_printf(c, "%s", response);

    // Cleanup
    (*Authenticated->logout_handler)();
    free(Authenticated);
}
```

Challenge 33 UaF

```
// REST: /ping
void rest_ping(struct mg_connection *c, struct http_message *hm) {
    // Answer - copy query_string and send it back
    int len = (int)hm->query_string.len;
    void* qs = malloc(len);
    memcpy(qs, hm->query_string.p, hm->query_string.len);

    mg_send_head(c, 200, len, "Content-Type: text/plain");
    mg_send(c, qs, len);

    free(qs);
}
```

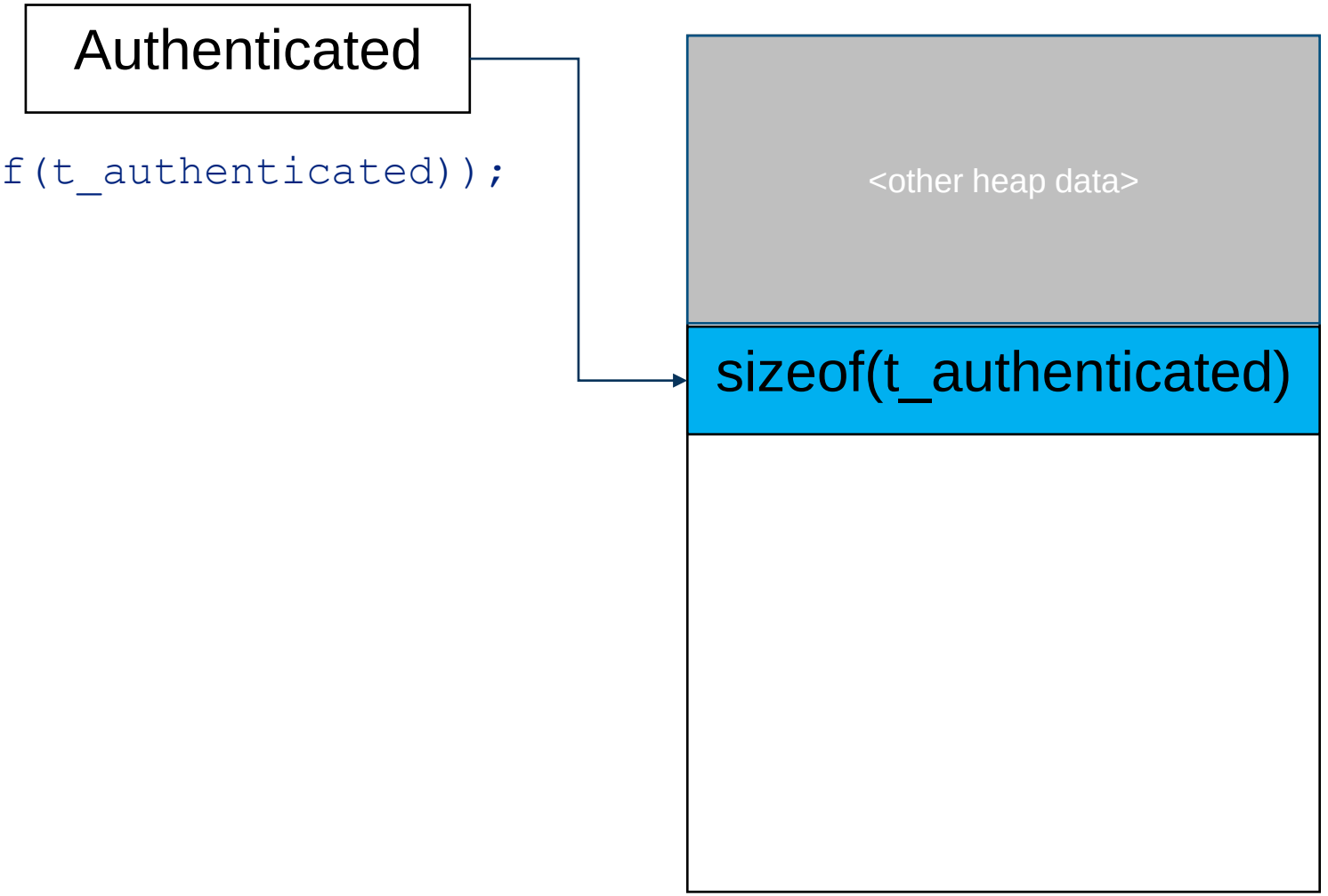
Challenge 33 UaF

Mongoose Web Server

- /login
  - Authenticated = malloc(sizeof(t_authenticated));
- /logout
  - free(Authenticated);
- /ping?asdf
  - malloc(sizeof(URL_QUERY));
  - free();

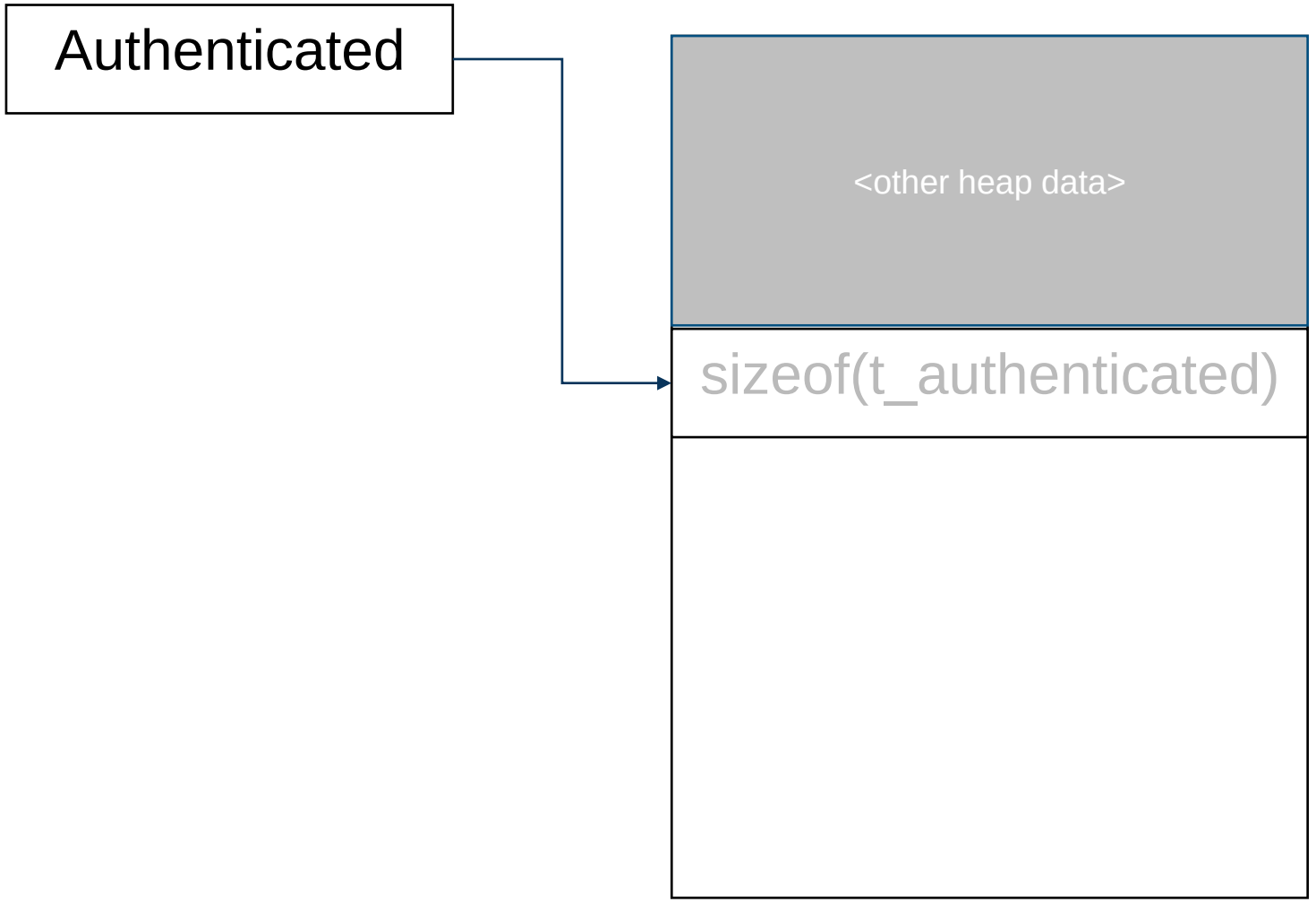
Challenge 33 UaF

```
curl localhost:8000/login
// Authenticated = malloc(sizeof(t_authenticated));
```



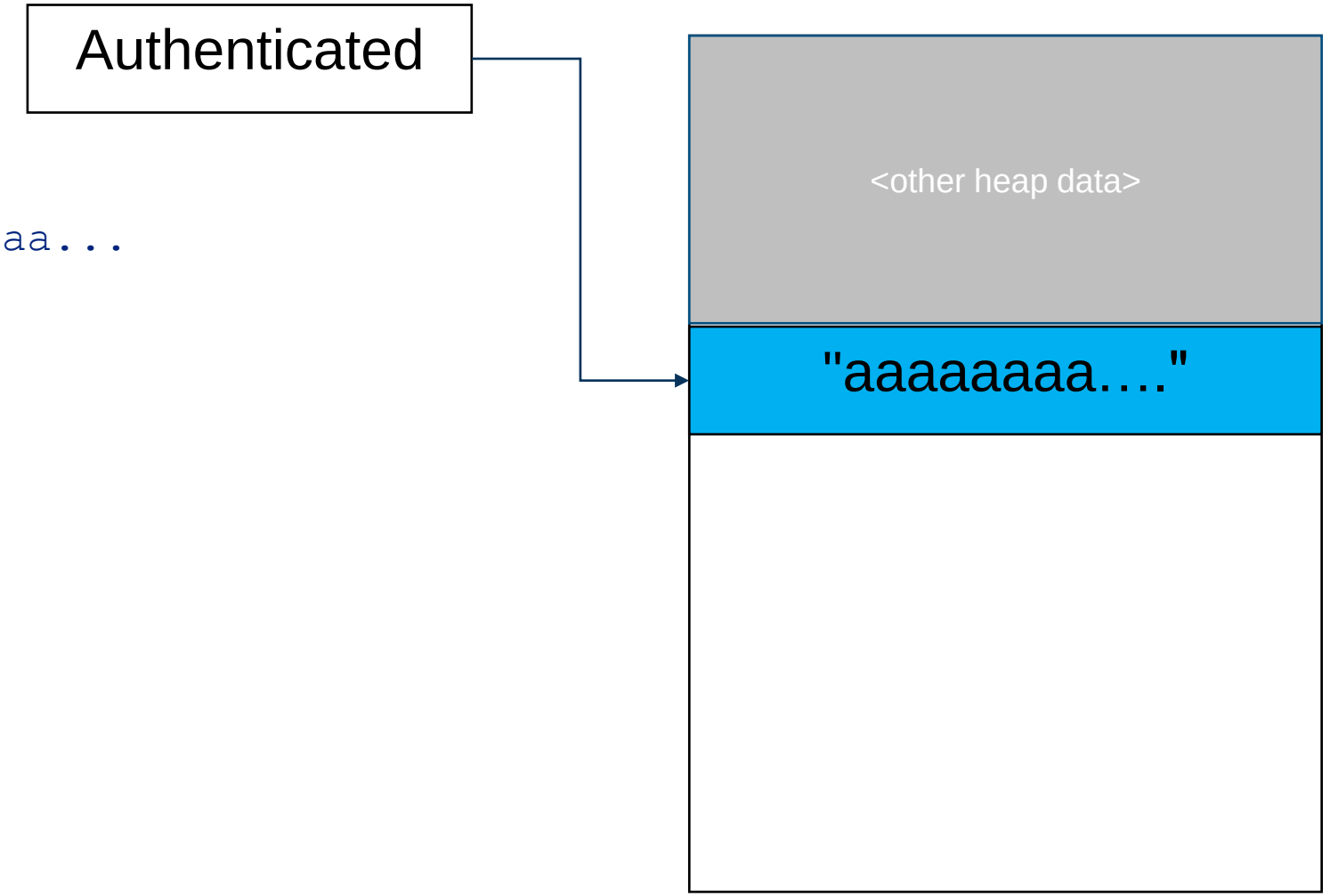
Challenge 33 UaF

```
curl localhost:8000/login
curl localhost:8000/logout
// Authenticated->function();
// free(Authenticated);
```



Challenge 33 UaF

```
curl localhost:8000/login
curl localhost:8000/logout
curl localhost:8000/ping?aaaaaaaa...
// malloc(strlen("aaaa..."));
```



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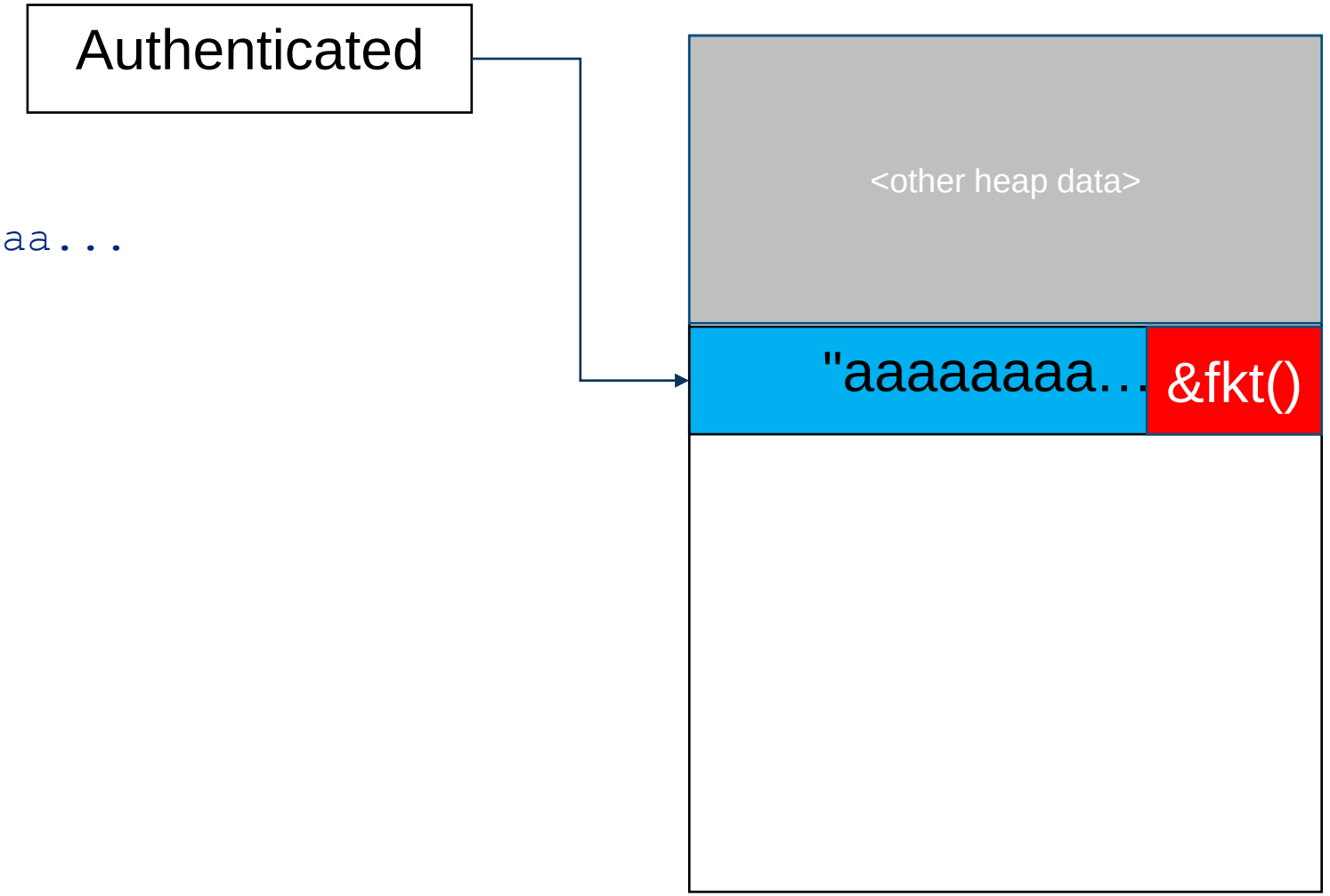


Conclusion

UaF:
Step 1: make two objects, with different types, point to the same object on the heap
Step 2: ???
Step 3: Profit!

Heap Attacks:
Use After Free (UAF)

Intermezzo

Use After Free

WebKit

Available for: iPhone 5 and later, iPad 4th generation and later, iPod touch 6th generation and later

Impact: Processing maliciously crafted web content may lead to arbitrary code execution

Description: A use after free issue was addressed through improved memory management.

CVE-2017-2471: Ivan Fratric of Google Project Zero

Kernel

Available for: iPhone 5 and later, iPad 4th generation and later, iPod touch 6th generation and later

Impact: An application may be able to execute arbitrary code with kernel privileges

Description: A use after free issue was addressed through improved memory management.

libc++abi

Available for: iPhone 5 and later, iPad 4th generation and later, iPod touch 6th generation and later

Impact: Demangling a malicious C++ application may lead to arbitrary code execution

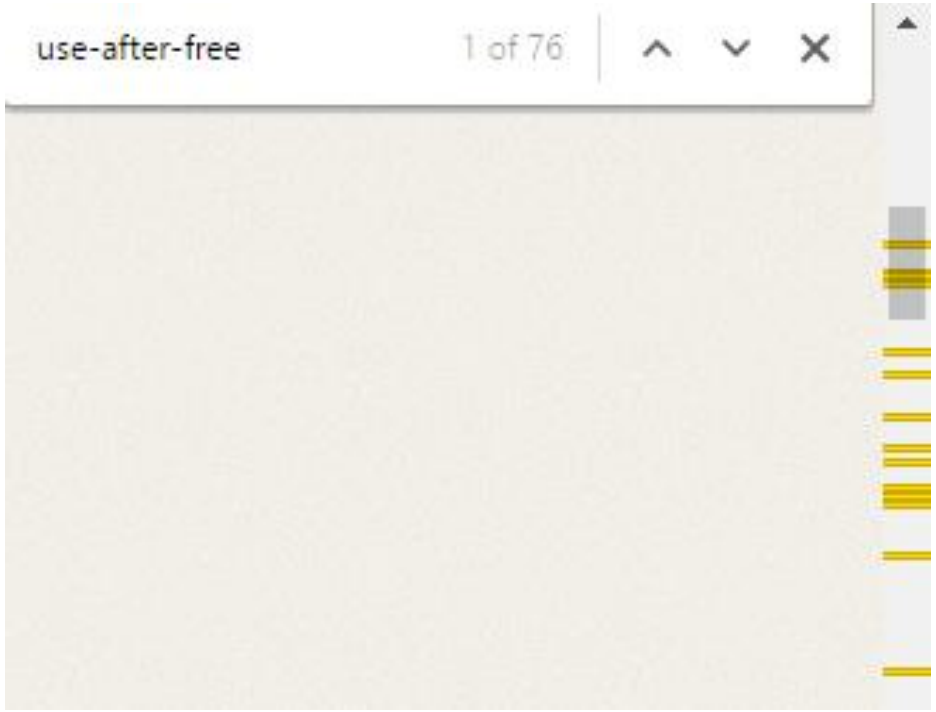
Description: A use after free issue was addressed through improved memory management.

CVE-2017-2441

Use After Free

Fixed in Firefox 48

2016-84	Information disclosure through Resource Timing API during page navigation
2016-83	Spoofing attack through text injection into internal error pages
2016-82	Addressbar spoofing with right-to-left characters on Firefox for Android
2016-81	Information disclosure and local file manipulation through drag and drop
2016-80	Same-origin policy violation using local HTML file and saved shortcut file
2016-79	Use-after-free when applying SVG effects
2016-78	Type confusion in display transformation
2016-77	Buffer overflow in ClearKey Content Decryption Module (CDM) during video playback
2016-76	Scripts on marquee tag can execute in sandboxed iframes
2016-75	Integer overflow in WebSockets during data buffering
2016-74	Form input type change from password to text can store plain text password in session restore file
2016-73	Use-after-free in service workers with nested sync events
2016-72	Use-after-free in DTLS during WebRTC session shutdown
2016-71	Crash in incremental garbage collection in JavaScript
2016-70	Use-after-free when using alt key and toplevel menus
2016-69	Arbitrary file manipulation by local user through Mozilla updater and callback



Use after free

Security Fixes and Rewards

Note: Access to bug details and links may be kept restricted until a majority of users are updated with a fix. We will also retain restrictions if the bug exists in a third party library that other projects similarly depend on, but haven't yet fixed.

This update includes 36 security fixes. Below, we highlight fixes that were contributed by external researchers. Please see the Chrome Security Page for more information.

[$7500][682194] **High** CVE-2017-5030: Memory corruption in V8. *Credit to Brendon Tiszka*
[$5000][682020] **High** CVE-2017-5031: Use after free in ANGLE. *Credit to Looben Yang*
[$3000][668724] **High** CVE-2017-5032: Out of bounds write in PDFium. *Credit to Ashfaq Ansari - Project Srishti*
[$3000][676623] **High** CVE-2017-5029: Integer overflow in libxslt. *Credit to Holger Fuhrmannek*
[$3000][678461] **High** CVE-2017-5034: Use after free in PDFium. *Credit to Ke Liu of Tencent's Xuanwu LAB*
[$3000][688425] **High** CVE-2017-5035: Incorrect security UI in Omnibox. *Credit to Enzo Aguado*
[$3000][691371] **High** CVE-2017-5036: Use after free in PDFium. *Credit to Anonymous*
[$1000][679640] **High** CVE-2017-5037: Multiple out of bounds writes in ChunkDemuxer. *Credit to Yongke Wang of Tencent's Xuanwu Lab (xlab.tencent.com)*
[$500][679649] **High** CVE-2017-5039: Use after free in PDFium. *Credit to jinmo123*
[$2000][691323] **Medium** CVE-2017-5040: Information disclosure in V8. *Credit to Choongwoo Han*
[$1000][642490] **Medium** CVE-2017-5041: Address spoofing in Omnibox. *Credit to Jordi Chancel*
[$1000][669086] **Medium** CVE-2017-5033: Bypass of Content Security Policy in Blink. *Credit to Nicolai Grødum*
[$1000][671932] **Medium** CVE-2017-5042: Incorrect handling of cookies in Cast. *Credit to Mike Ruddy*
[$1000][695476] **Medium** CVE-2017-5038: Use after free in GuestView. *Credit to Anonymous*
[$1000][683523] **Medium** CVE-2017-5043: Use after free in GuestView. *Credit to Anonymous*
[$1000][688987] **Medium** CVE-2017-5044: Heap overflow in Skia. *Credit to Kushal Arvind Shah of Fortinet's FortiGuard Labs*
[$500][667079] **Medium** CVE-2017-5045: Information disclosure in XSS Auditor. *Credit to Dhaval Kapil (vampire)*
[$500][680409] **Medium** CVE-2017-5046: Information disclosure in Blink. *Credit to Masato Kinugawa*

Security: Vulnerability lists

Intermezzo:

- Secure products:
  - Mention security fixes (don’t hide it)
  - Have a website with all fixed security vulnerabilities
  - As pentest: Can see which vulnerabilities are in which versions
  - Vendor is open, up to date and ready for security issues
- Bad products:
  - Don’t have a page with vulnerabilities
  - Don’t mention security fixes in changelogs
  - Vendor hides, doesn’t handle, obfuscate security issues

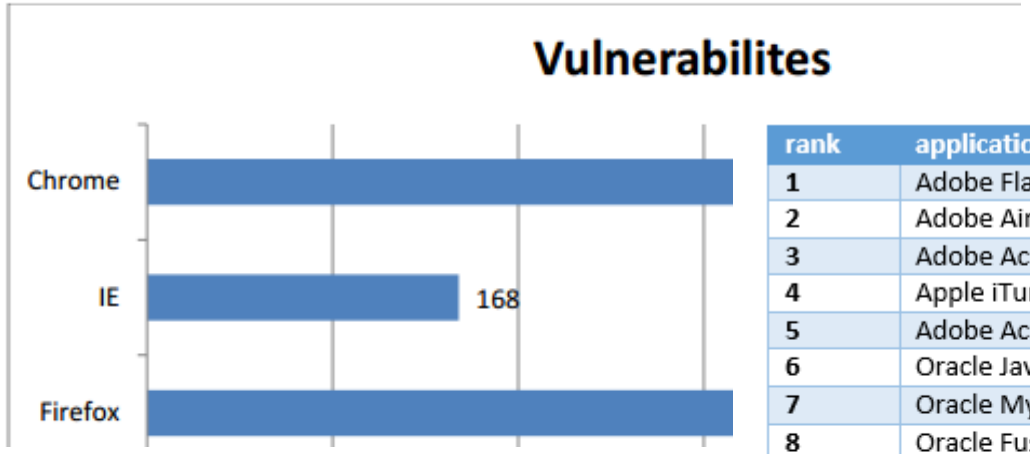
Security: CVE

CVE:

- Common Vulnerabilities and Exposures
- A vulnerability get a CVE (e.g. CVE-2017-1234)
  - Which software is affected
  - Which version
  - When did it got fixed
  - …

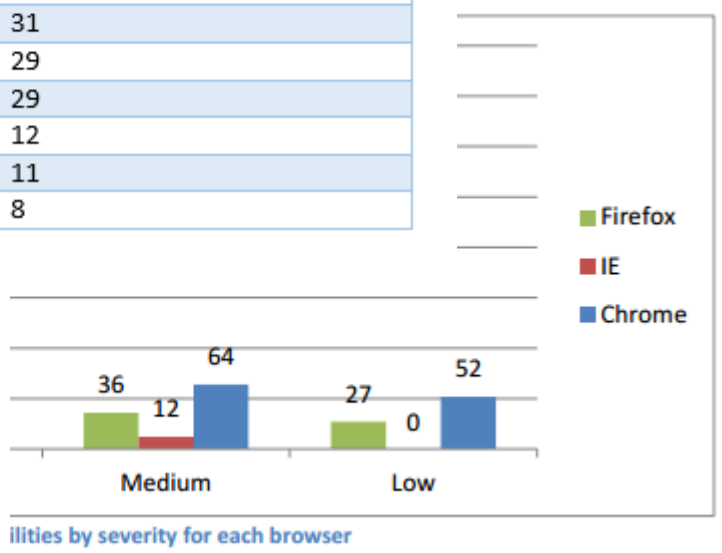
Security: CVE

rank	browser	number of vulnerabilities
1	Microsoft Internet Explorer	231
2	Google Chrome	187
3	Mozilla Firefox	178
4	Apple Safari	135
5	Mozilla Firefox Extended Support Release	94



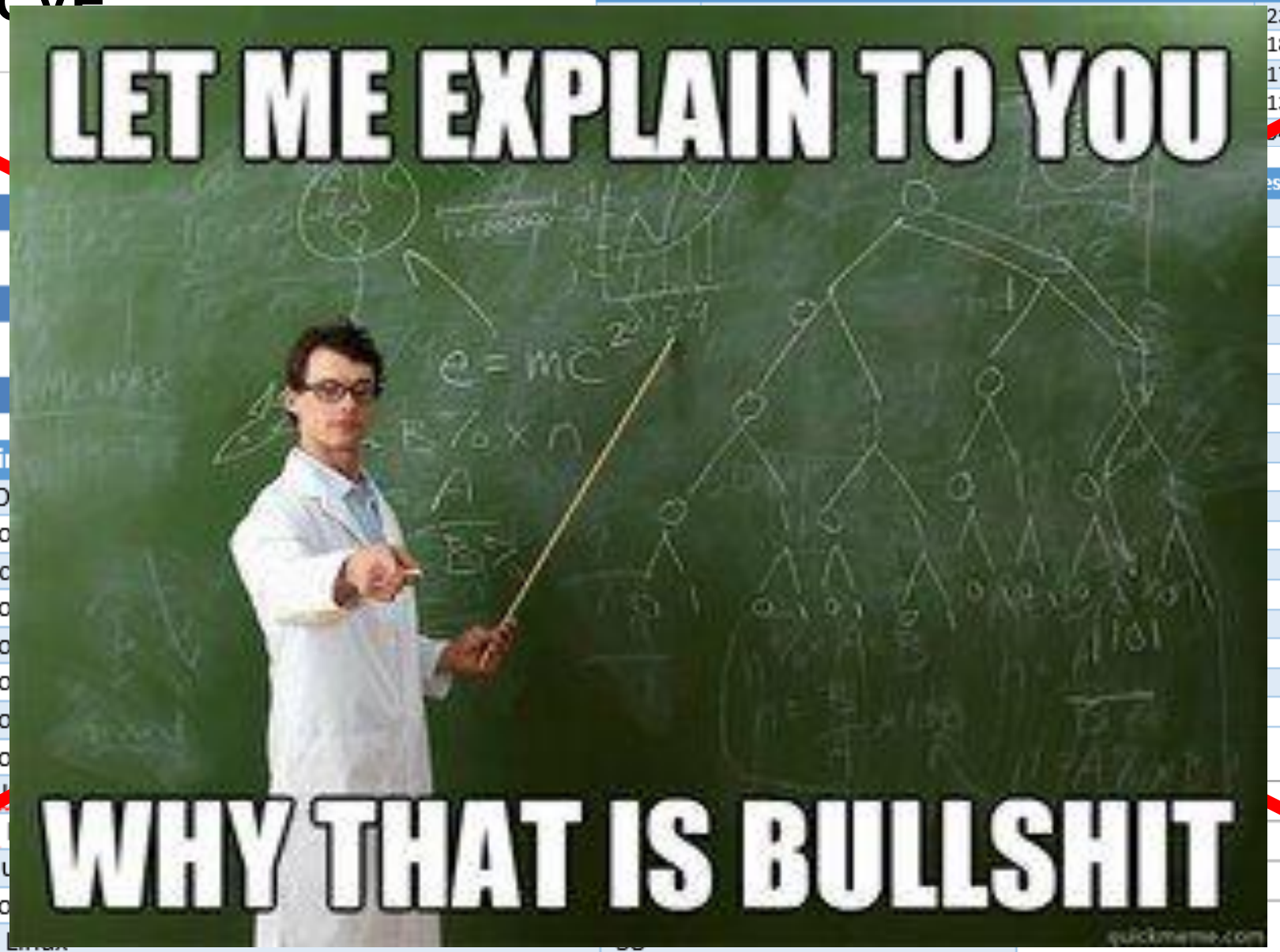
rank	application	number of vulnerabilities
1	Adobe Flash Player	314
2	Adobe Air, SDK, and Compiler	246
3	Adobe Acrobat and Reader	129
4	Apple iTunes	100
5	Adobe Acrobat Document Cloud and Reader	97
6	Oracle Java Runtime Environment and JDK	80
7	Oracle MySQL	76
8	Oracle Fusion Middleware	68
9	Apple TV application	57
10	Oracle E-Business Suite	37
11	OpenSSL	34
12	Wireshark	33
13	MediaWiki	31
14	Mozilla Thunderbird	29
15	Oracle Database Server	29
16	Microsoft Office 2007	12
17	Microsoft Office 2010	11
18	Microsoft Office 2013	8

rank	operating system	
1	Apple OS X	
2	Microsoft Windows Server 2012	
3	Canonical Ubuntu Linux	
4	Microsoft Windows 8.1	
5	Microsoft Windows Server 2008	
6	Microsoft Windows 7	
7	Microsoft Windows 8	
8	Microsoft Windows Vista	135
9	openSUSE	121
10	Debian Linux	111
11	The Linux Kernel	77
12	Microsoft Windows 10	53
13	Fedora Linux	38
14	Microsoft Windows 2003	36
15	Xen OS	34



ilities by severity for each browser

Security: CVE



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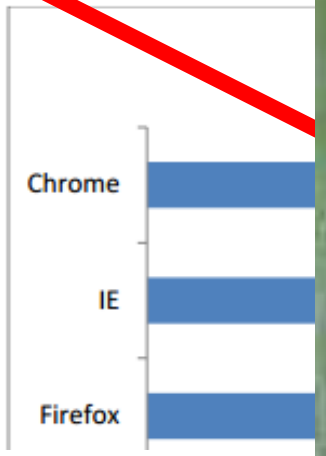
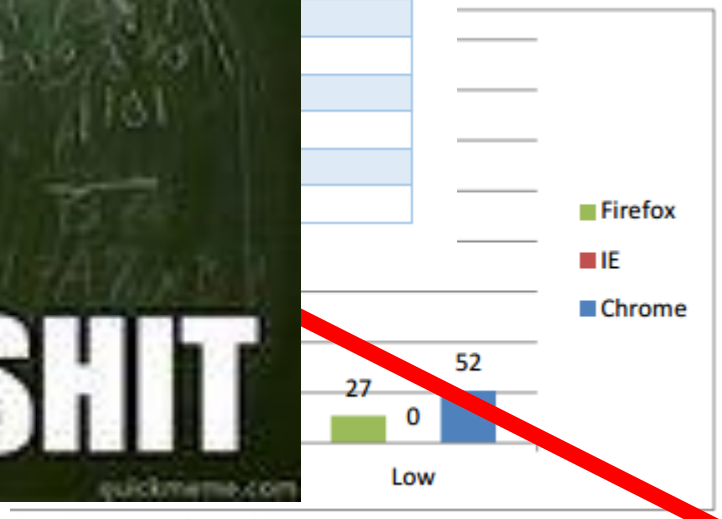
		178
		135
		94



rank	operati
1	Apple O
2	Microso
3	Canonic
4	Microso
5	Microso
6	Microso
7	Microso
8	Microso
9	openSU
10	Debian
11	The Linu
12	Microso
13	Fedora Linux
14	Microsoft Windows 2003
15	Xen OS



ilities by severity for each browser

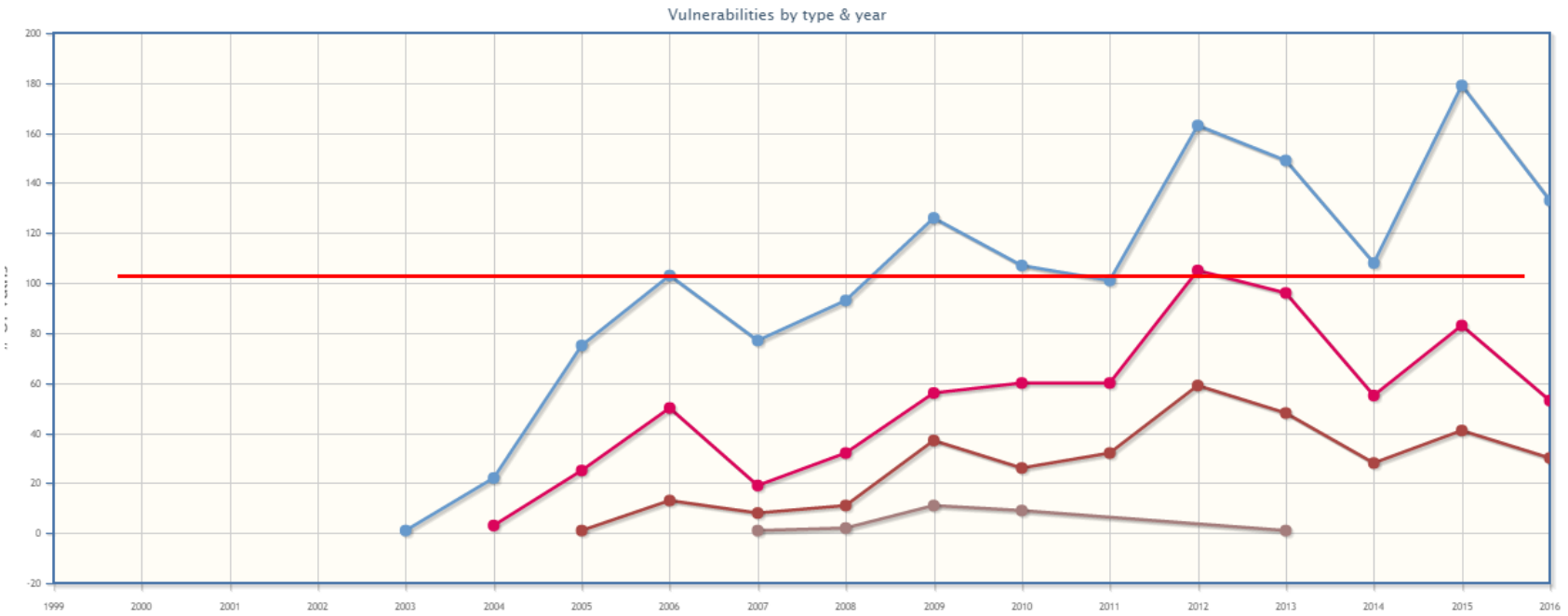
Security: CVE

Weakness comparison fails: (not just CVE)

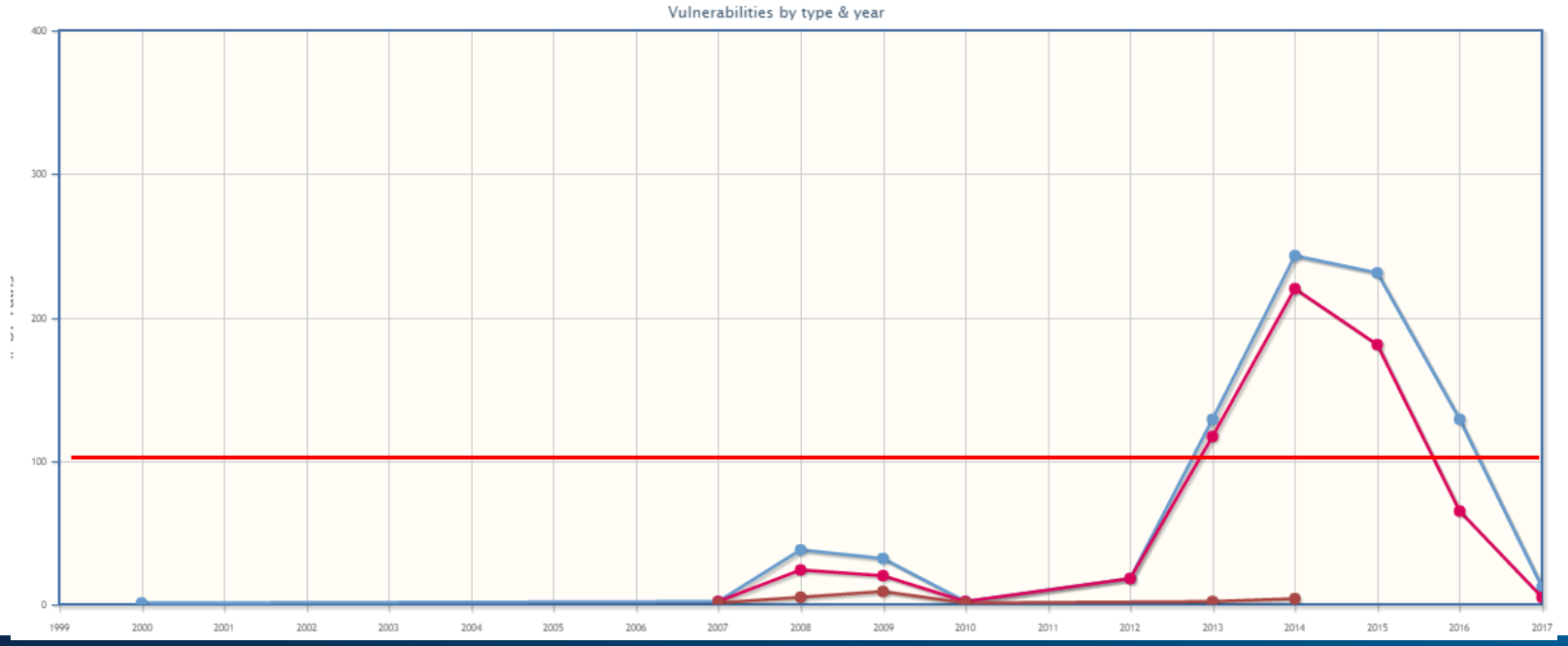
- Scope: “Windows vs Linux”
  - What is in Linux? Linux Kernel? Suse? LIBC? Bash? Apache?
  - What is in Windows? Internet Explorer? IIS?
- Severity mismatch
  - When is a vulnerability “critical”? When is it “high”?
  - Microsoft categorizes differently than Mozilla, or Google
- Number of vulnerabilities in CVE / bulletin
  - 1 vulnerability, one CVE / securtiy bullettin ?
  - 1 CVE for each product affected? (Cisco: RCE in product x, y, z)
  - 1 CVE for each individual bug? (e.g. UAF in component x, y, z)
- Vulnerablity disclosure
  - CVE’s for all the bugs found internally? (e.g. fuzzing)
  - CVE for all the bugs found by looking for similar bugs?
- …

-> Don’t compare different product’s security issues by counting <-

FF


Vulnerabilities by type & year
200
180
160
140
120
100
80
60
40
20
0
-20
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

IE


Vulnerabilities by type & year
400
300
200
100
0
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

Heap Attacks:
Use After Free (UAF)

Introduction

Heap Attack: UAF

UAF:

```
Use after free
```

Or more correctly:

```
Use an object, after the memory it has been pointing to has been freed,
and now a different object is stored at that location
```

Heap Attack: UAF

So, what is UAF?

- We have a pointer (of type A) to an **object**
- The **object** get's **free**()'d
  - This means that the memory allocater marks the object as free
  - The object will not be modified!
  - (Similar to deleting a file on the harddisk)
  - The pointer is still valid
- **Another object** of type B (of similar size) get's **allocated**
- Memory allocator returns the previously free'd object memory space

- Attacker has now **a pointer (type A) to another object (type B)**!
- This object can be modified
  - Depending on the types A and B

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/