Malloc Lab

15/18-213: Introduction to Computer Systems
1011st Recitation, Apr. 2, 2012

Outline

- Overview
- Naïve Implicit List Allocator
- Getting Started
- Evaluation
- Debugging Tips, Misc

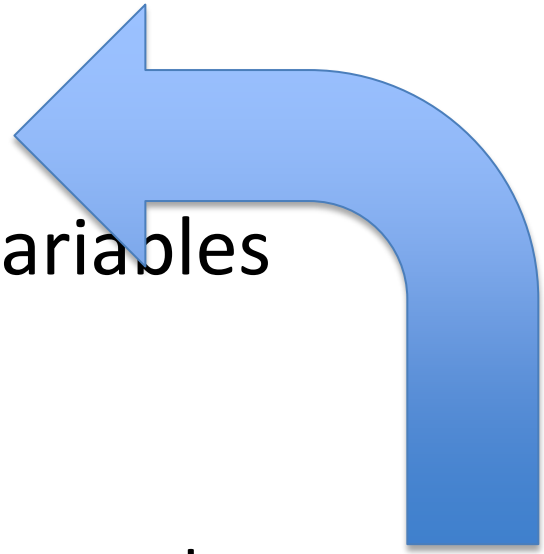
You will implement

- malloc()
- calloc()
- realloc()
- free()
- mm_init()
  - setup whatever you need to
  - called before any calls to malloc
- mm_checkheap()
  - a debug function

In other words, you will manage the heap yourself.

You have

- mem_sbrk()
- unused heap space
- a handful of *scalar* variables
  - no arrays
  - no structs
  - where will you keep your data structures?



mem_sbrk()

- a wrapper around sbrk()
  - sbrk(incr) asks the operating system for incr more bytes of heap space at the end of the current heap
  - has relatively high overhead

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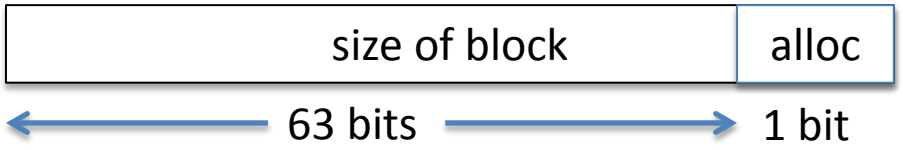
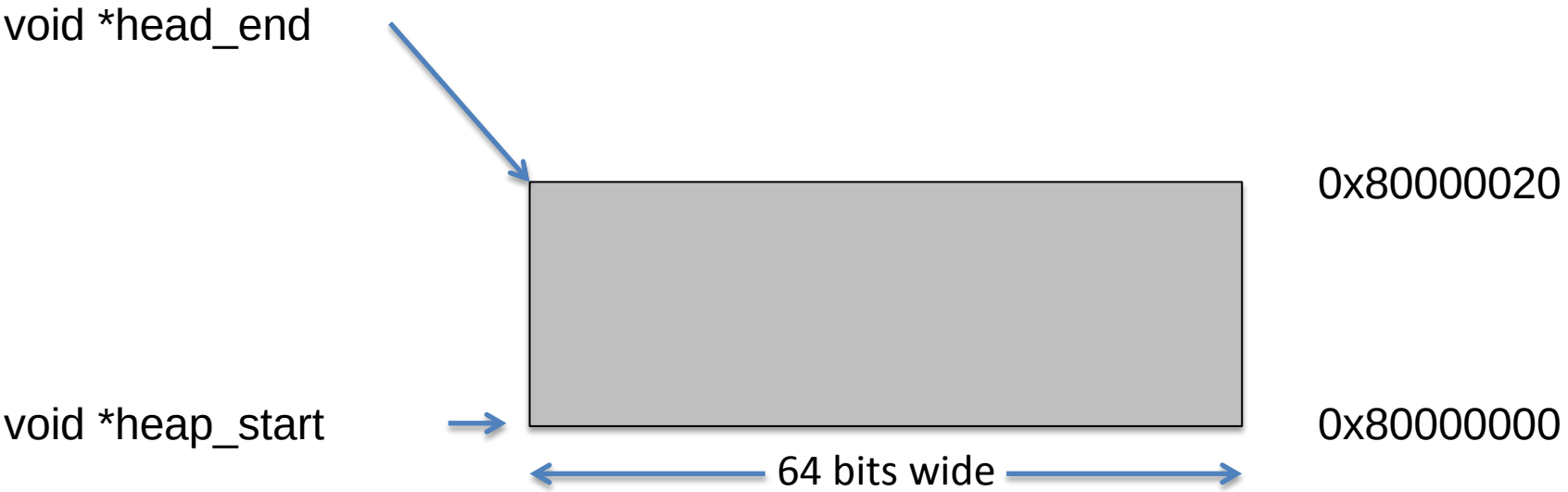
Before mm_init()

During mm_init()

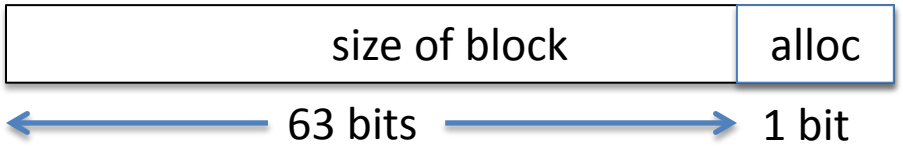
header/footer field format:

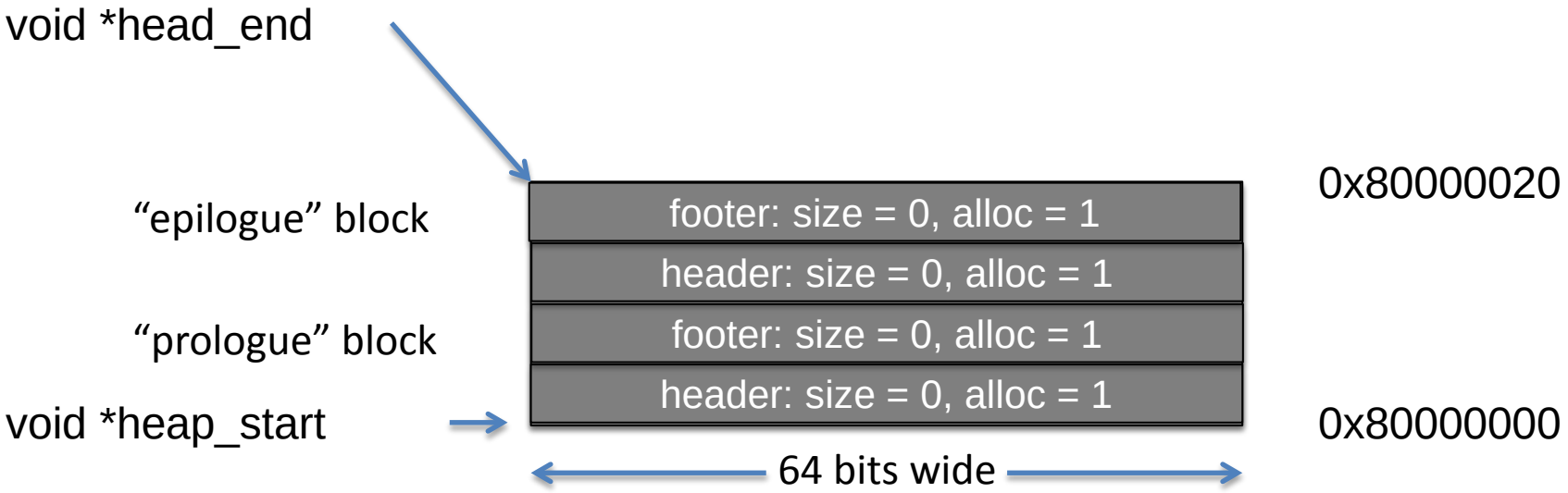




During mm_init()

header/footer field format:





After mm_init()

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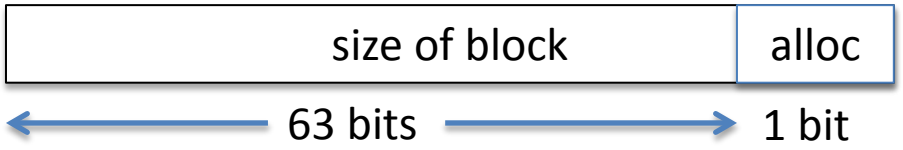
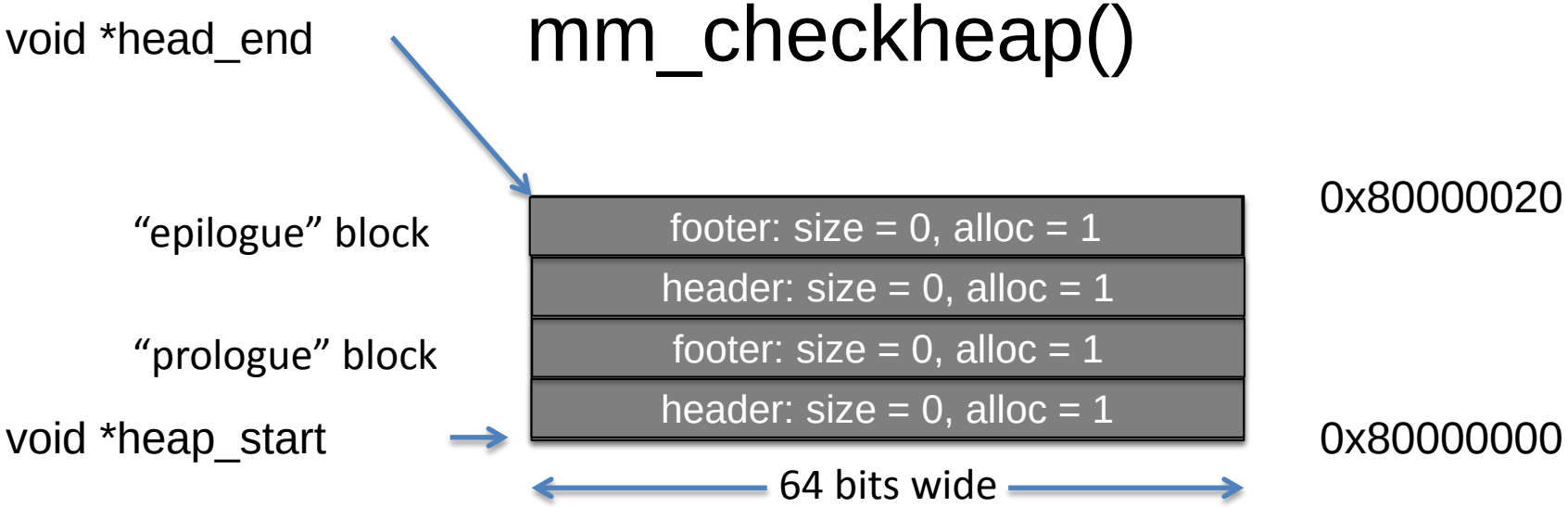
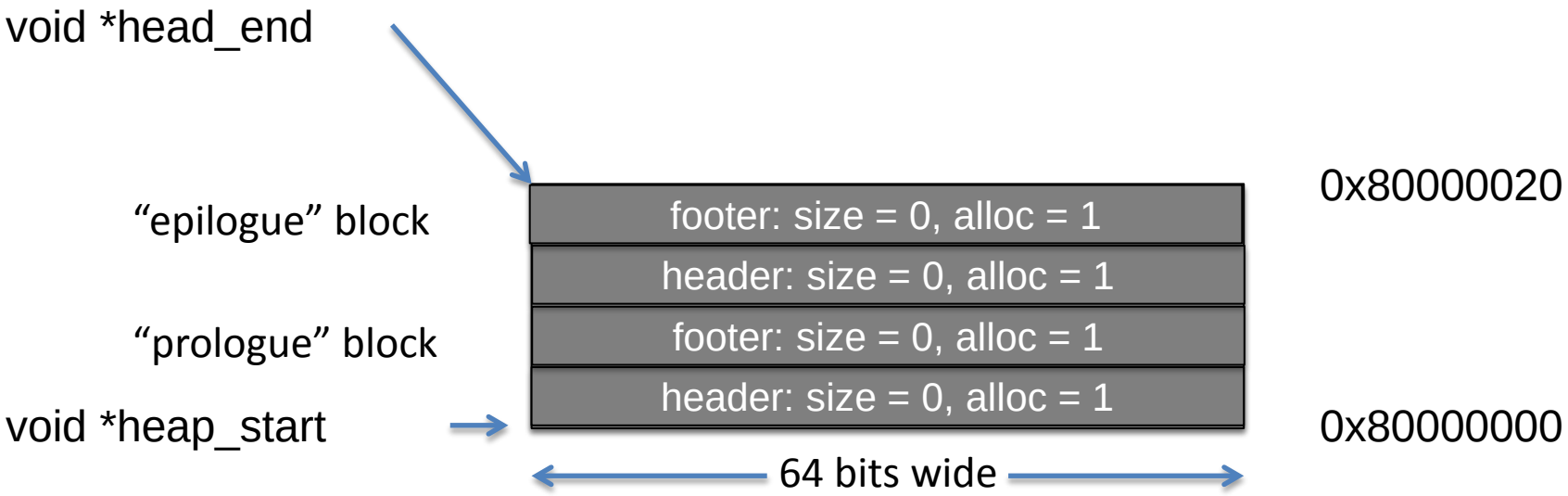


We've set up our invariants – at this point we can implement mm_checkheap()



Aside: mm_checkheap()

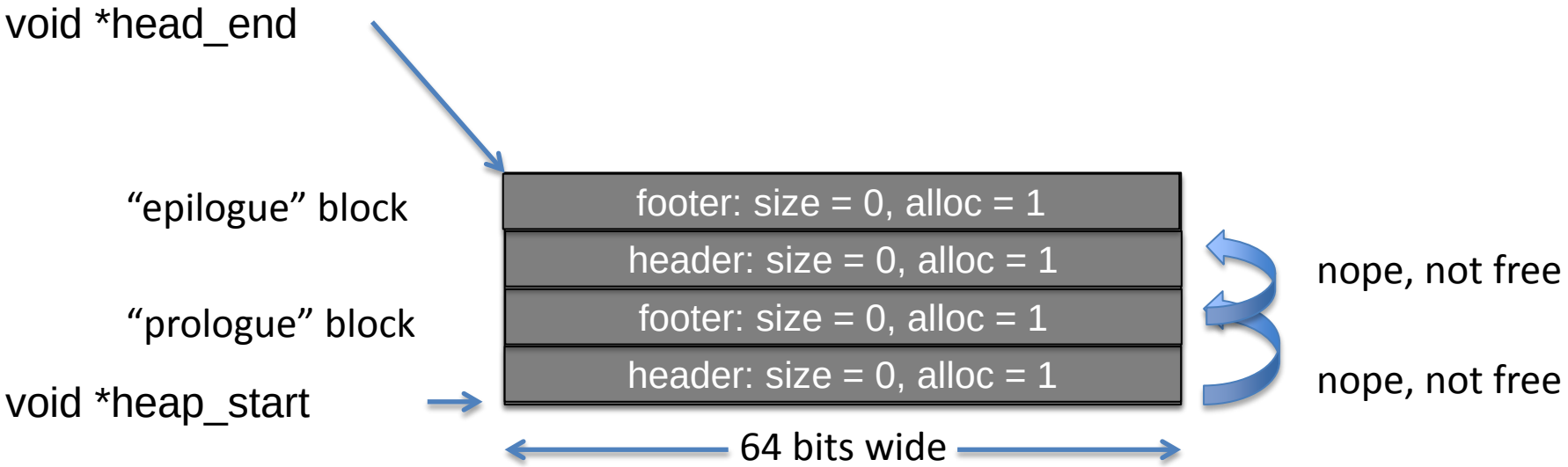
- mm_checkheap()
  - called between malloc()/free() operations
  - should check invariants are obeyed
  - quickly find bugs



Call to malloc(0x100)

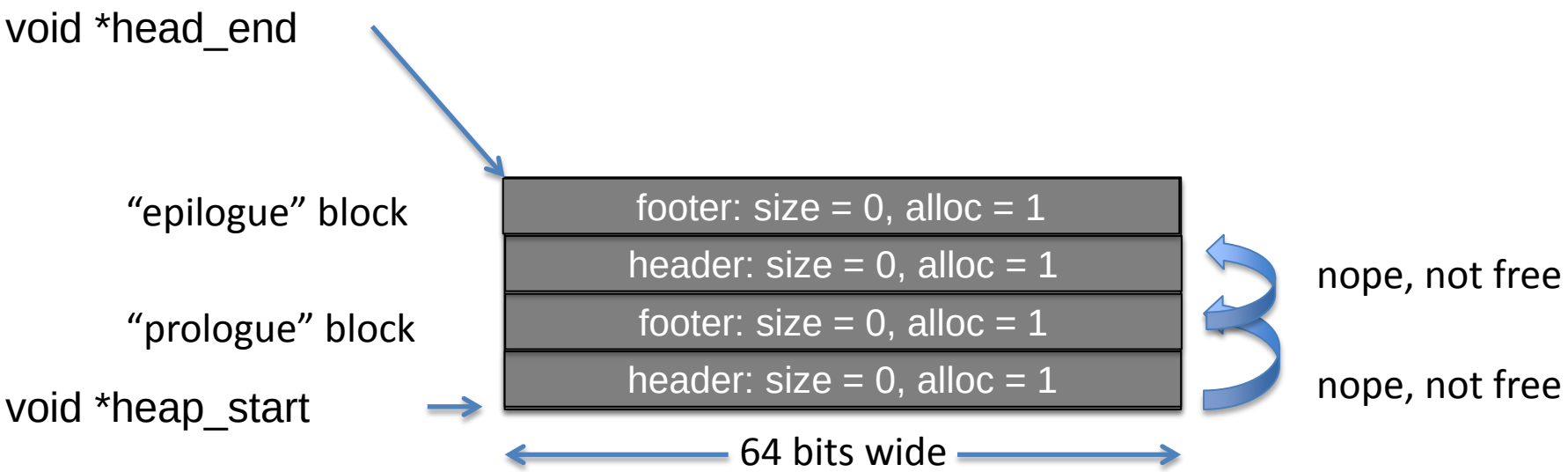
Search through heap for a free block

Use the fact that header = start of previous block's footer + 8 bytes

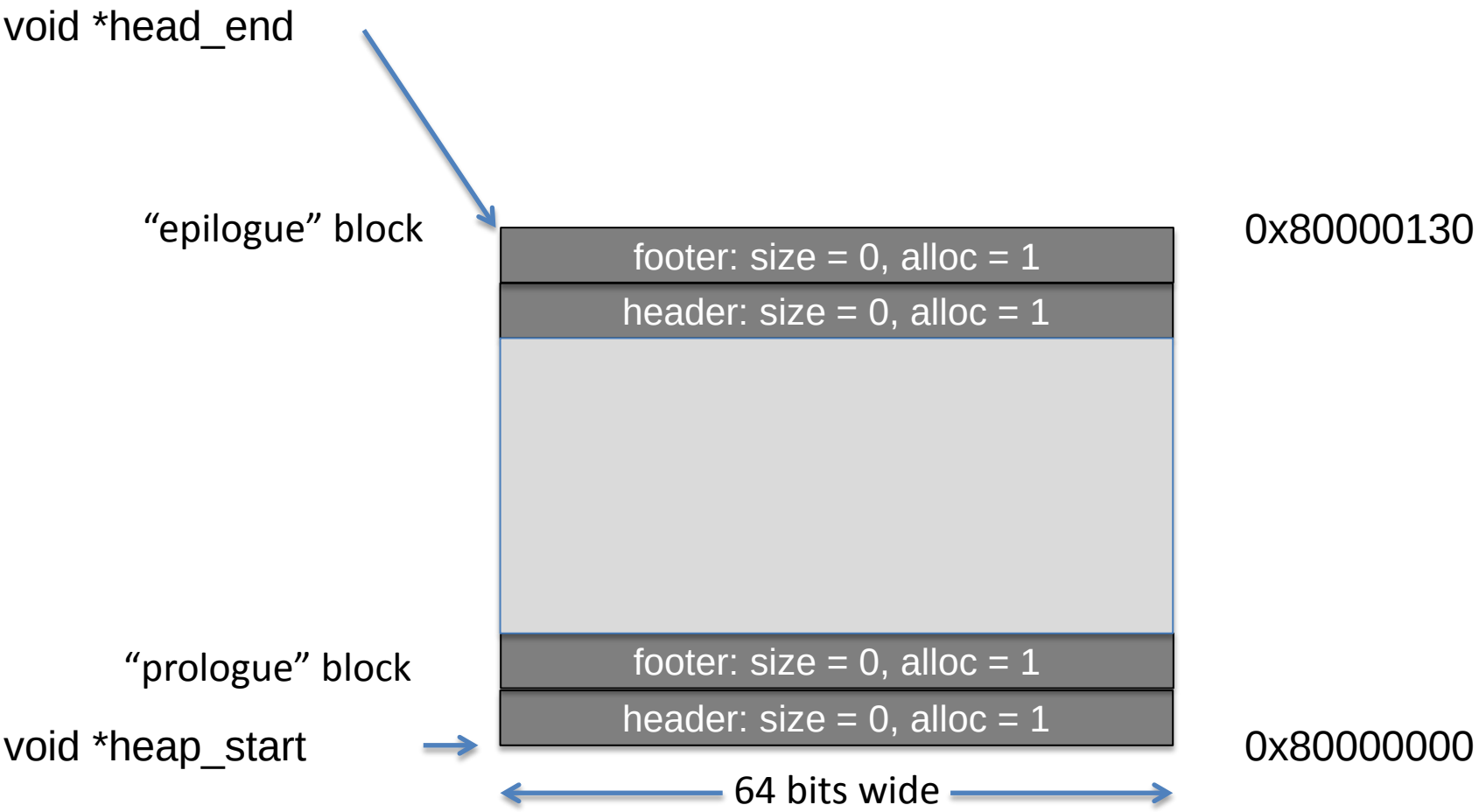


Call to malloc(0x100)

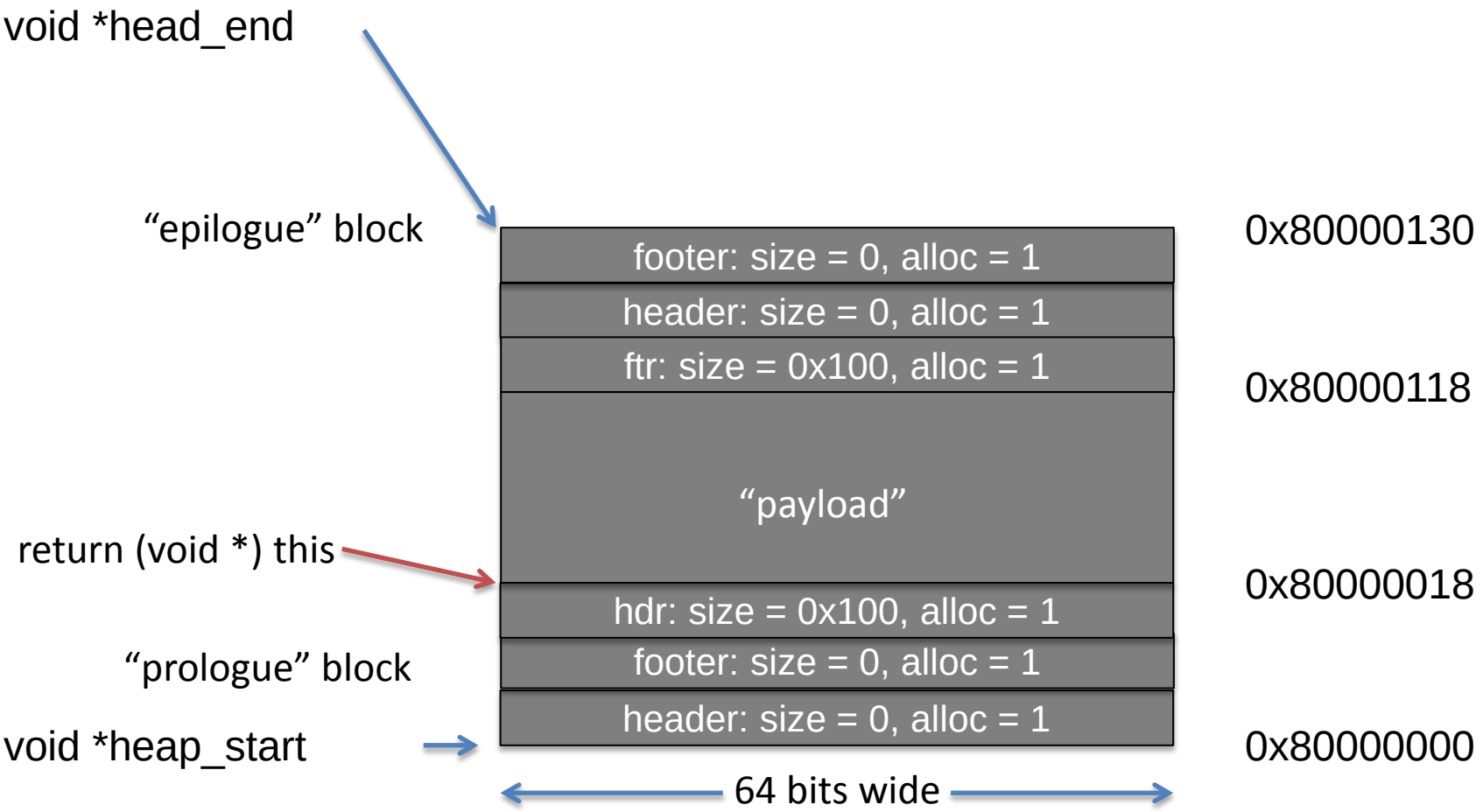
Search failed to find free block. Now what?



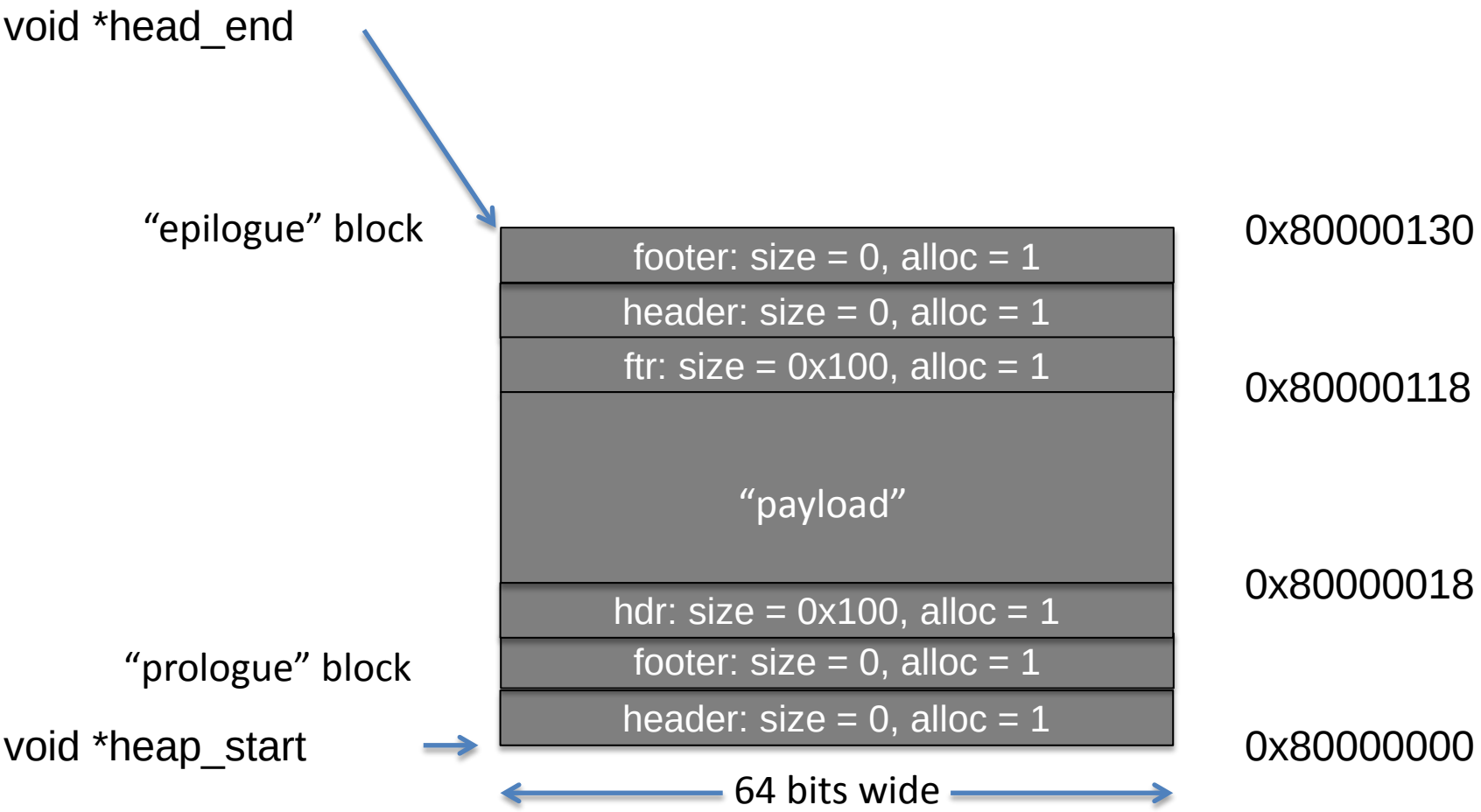
Call to malloc(0x100)



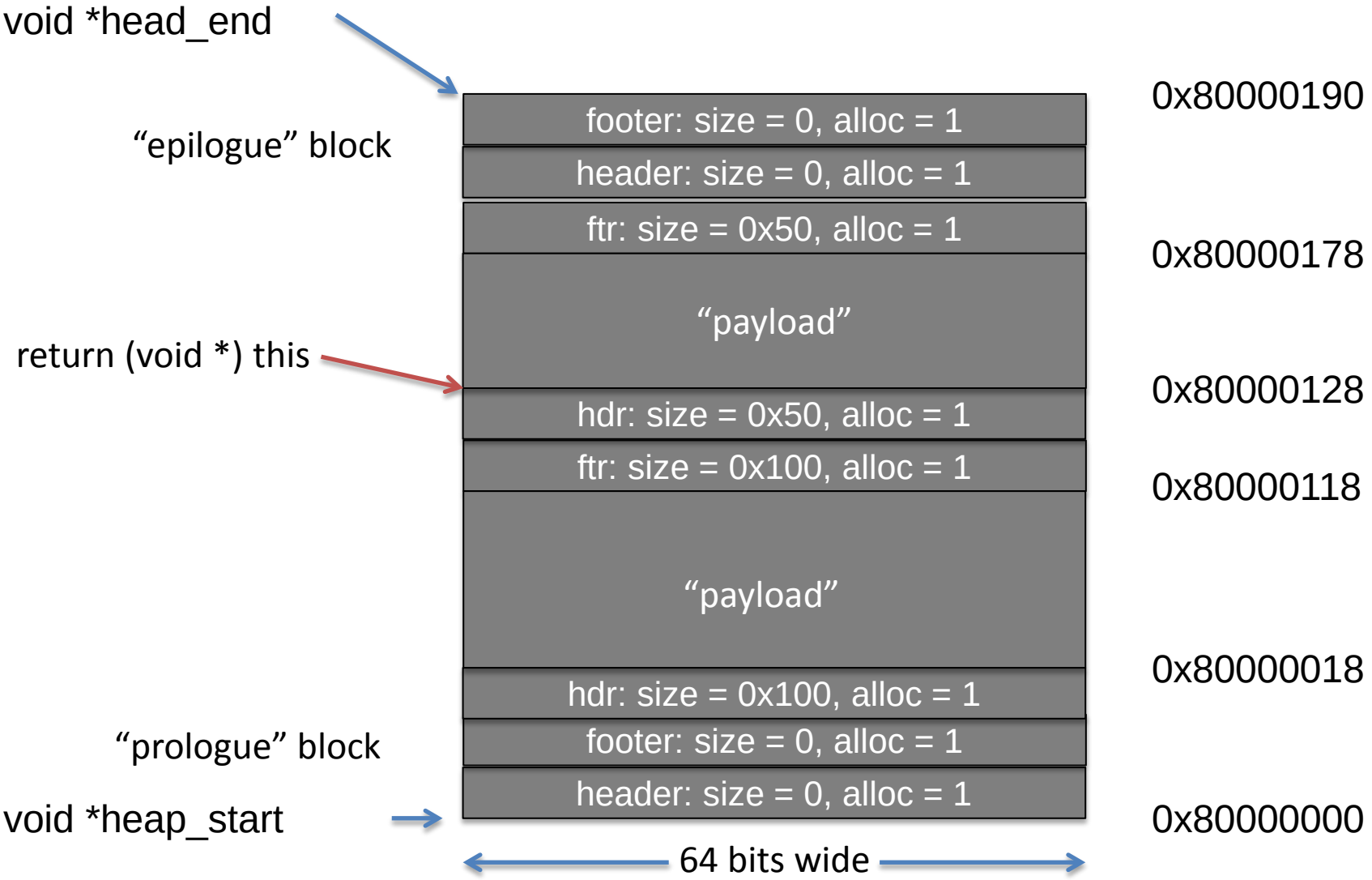
Call to malloc(0x100)



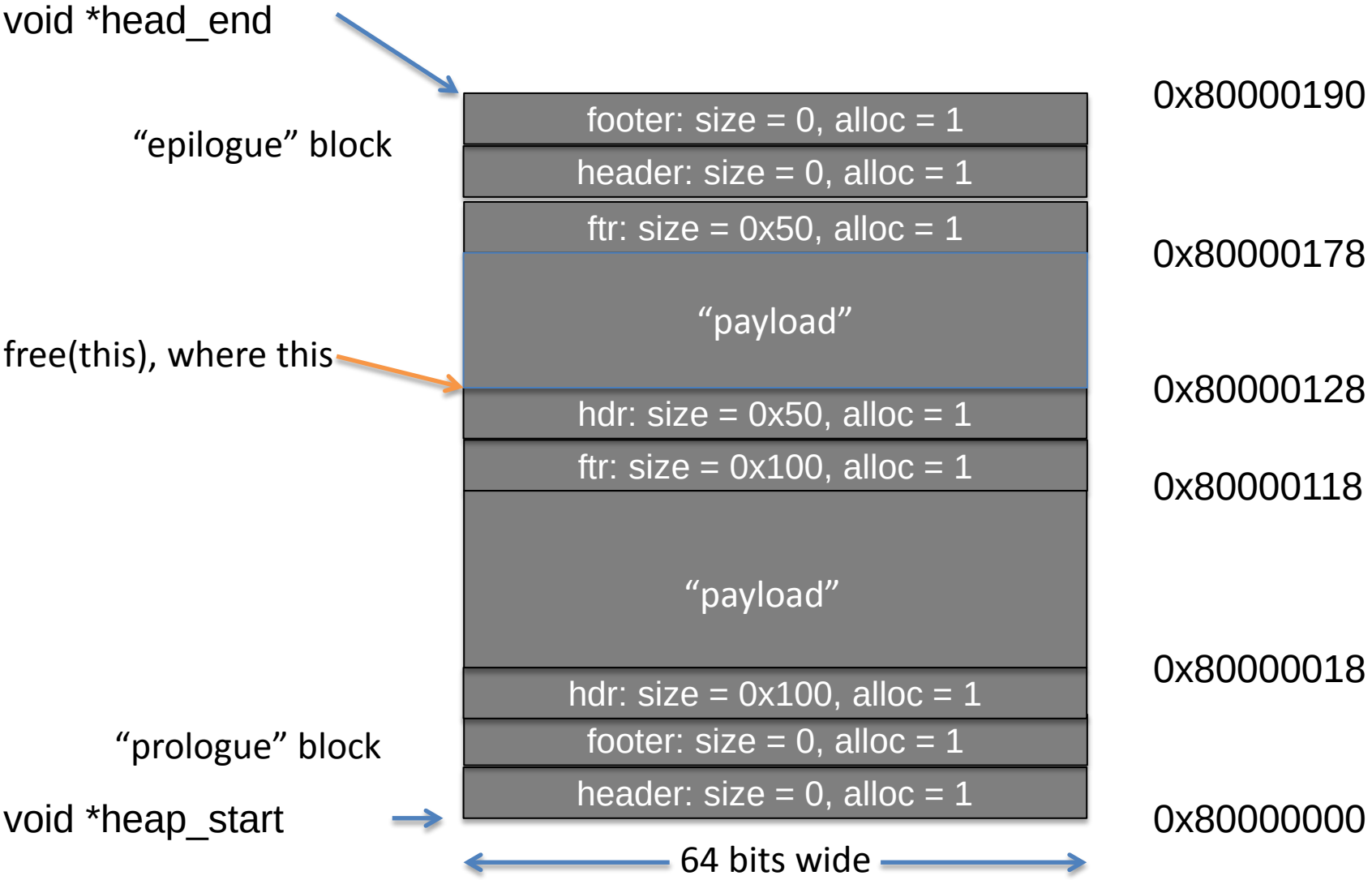
Now, Call to malloc(0x50)



Now, Call to malloc(0x50)



suddenly,free(0x80000128)



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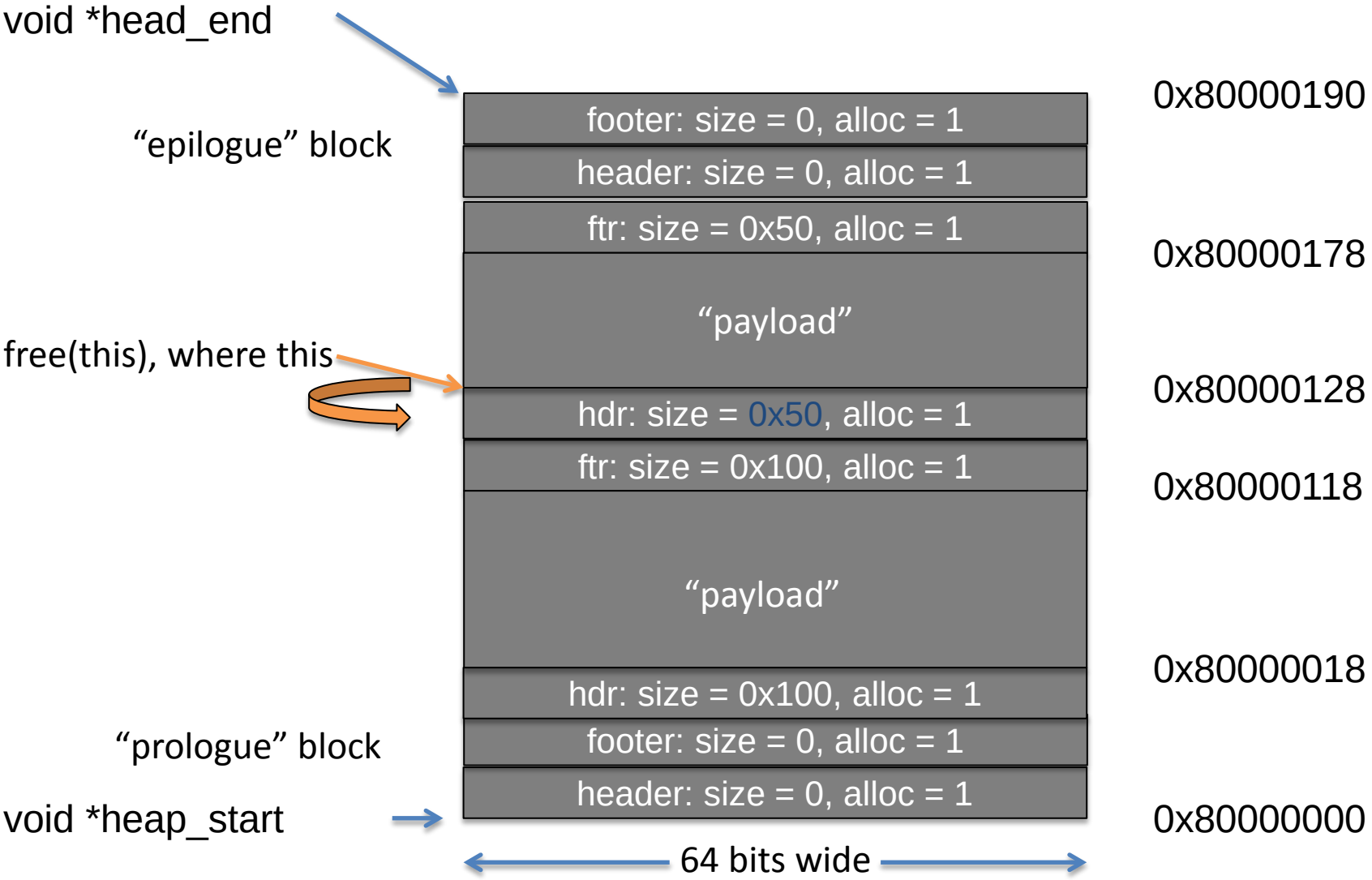

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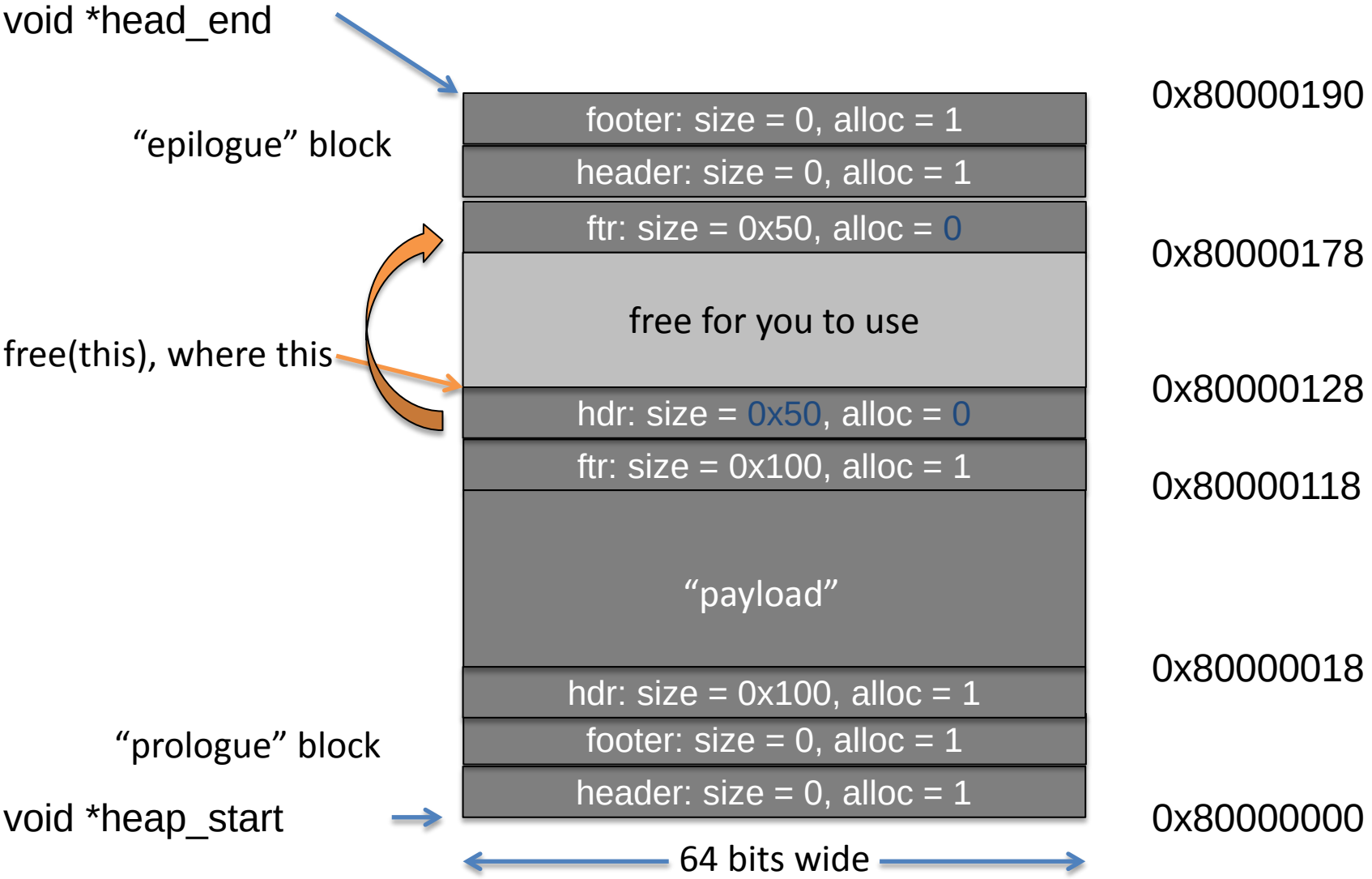
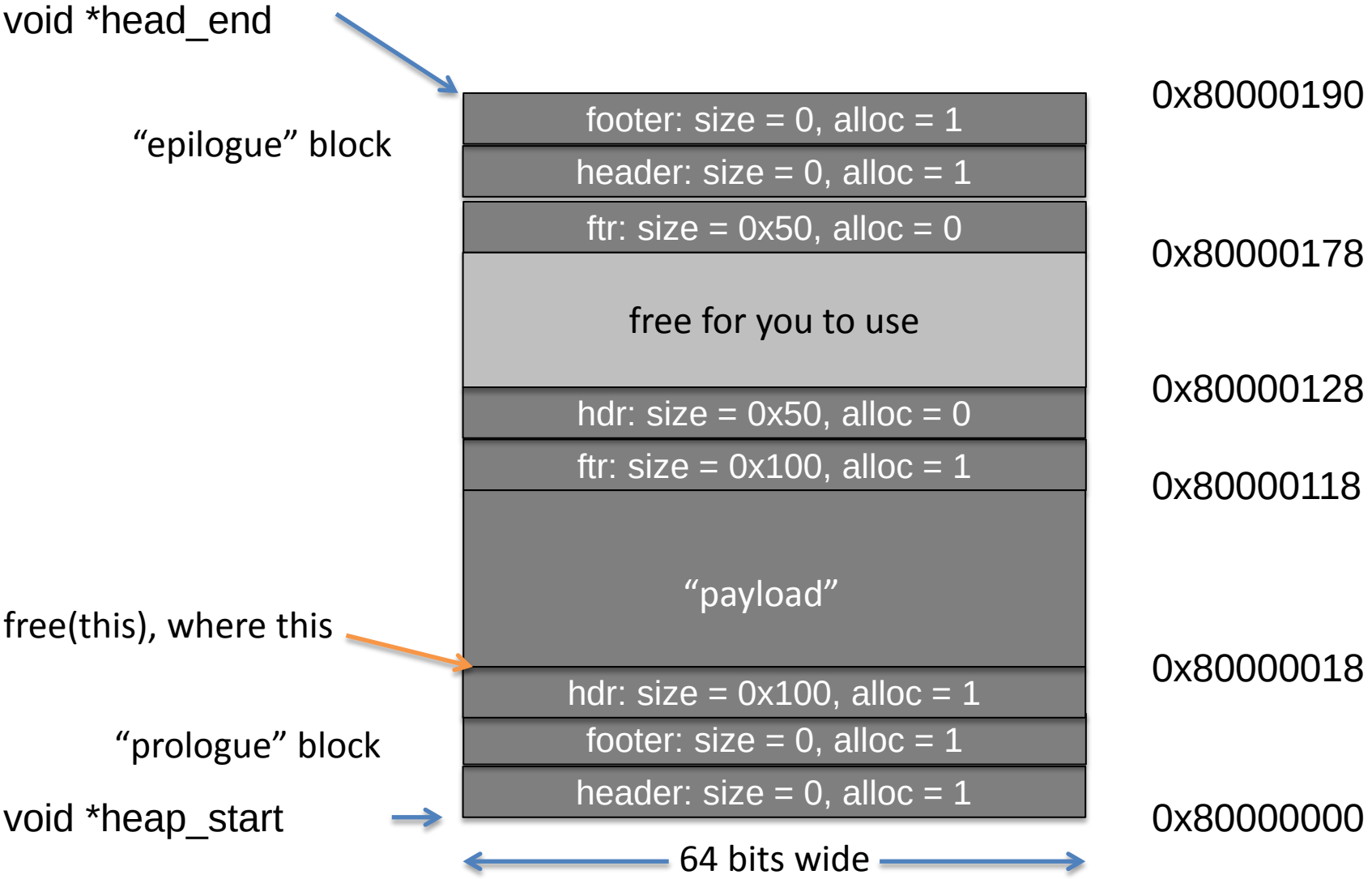


suddenly,free(0x80000018)



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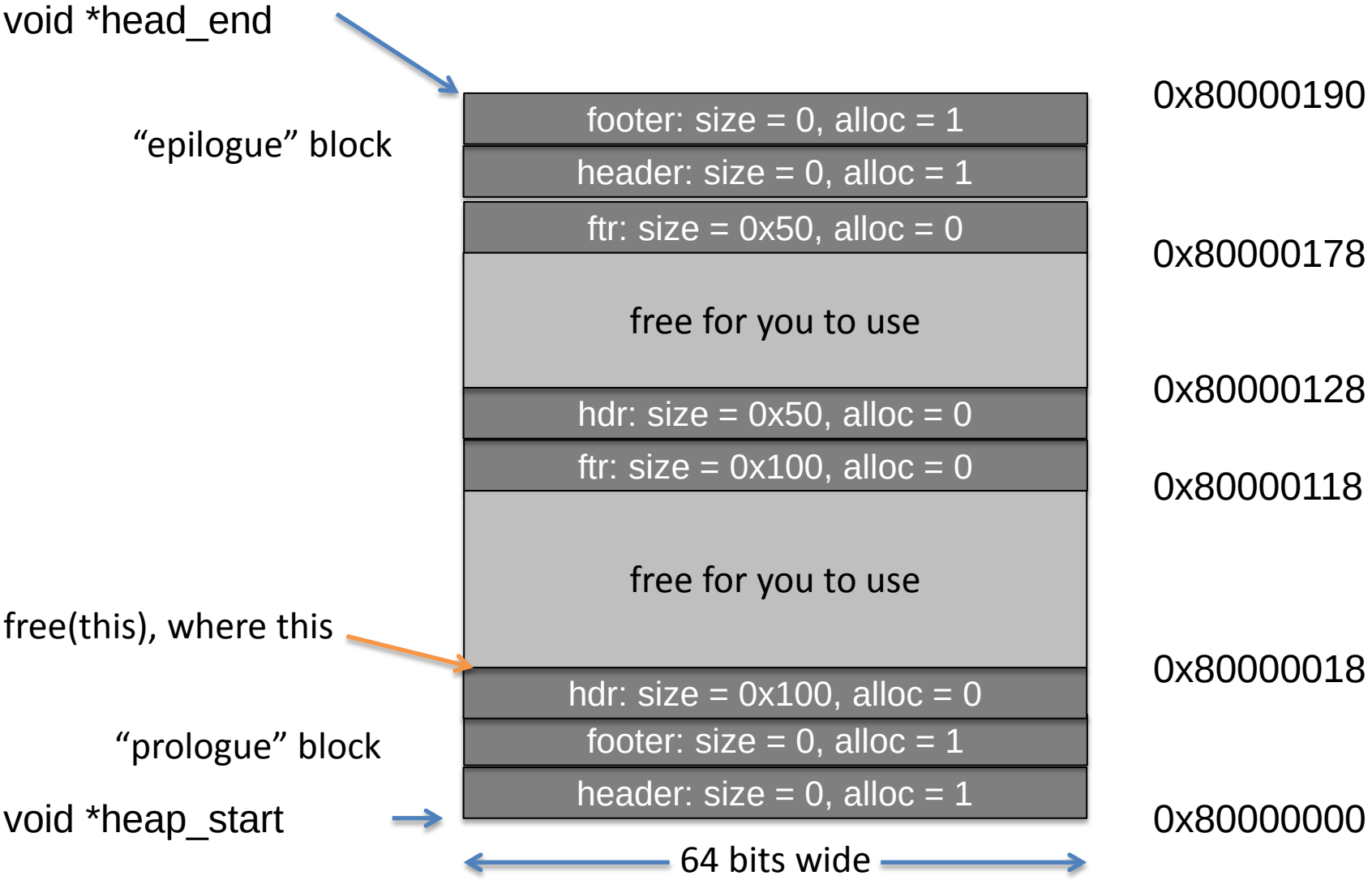

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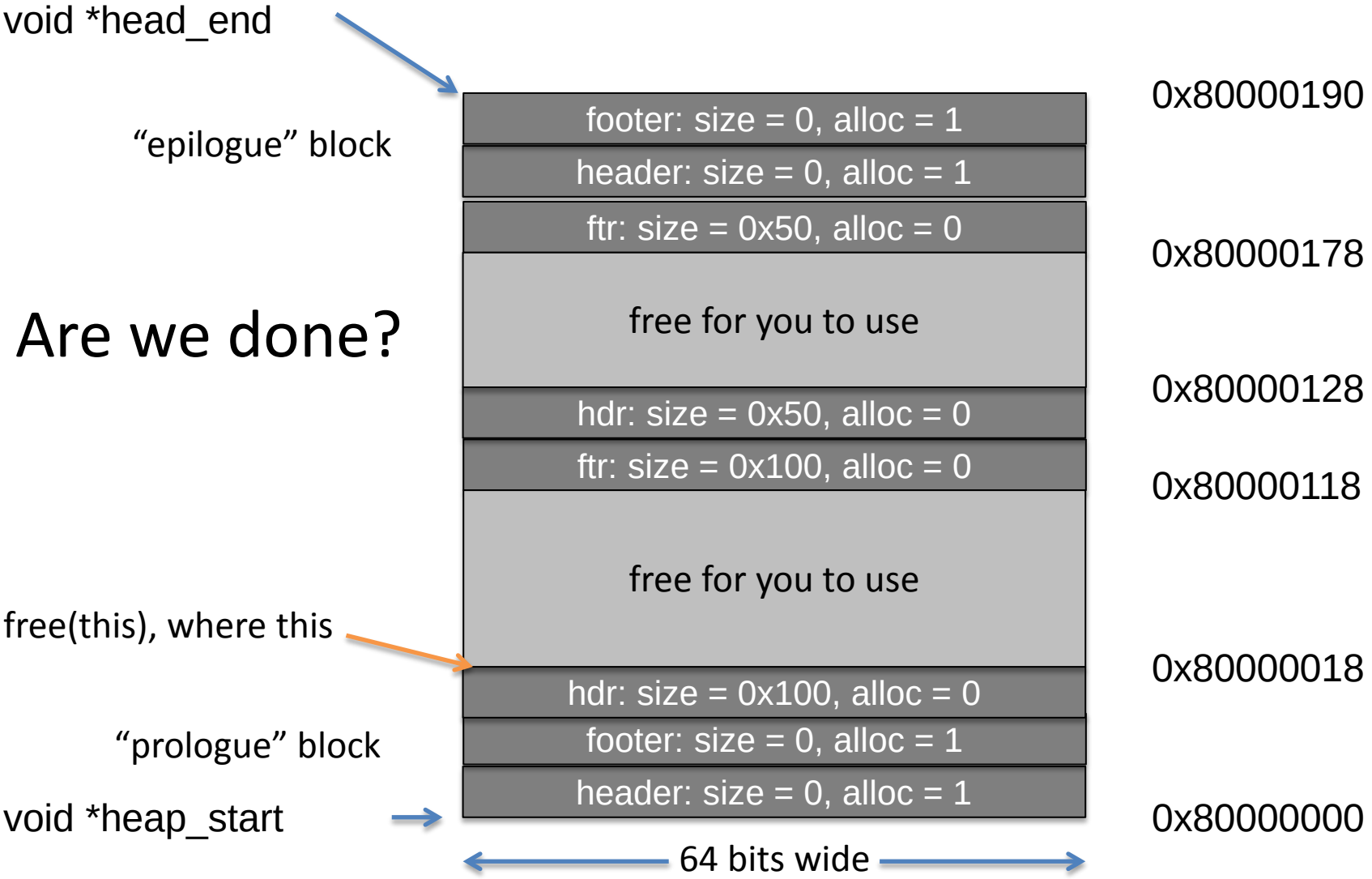
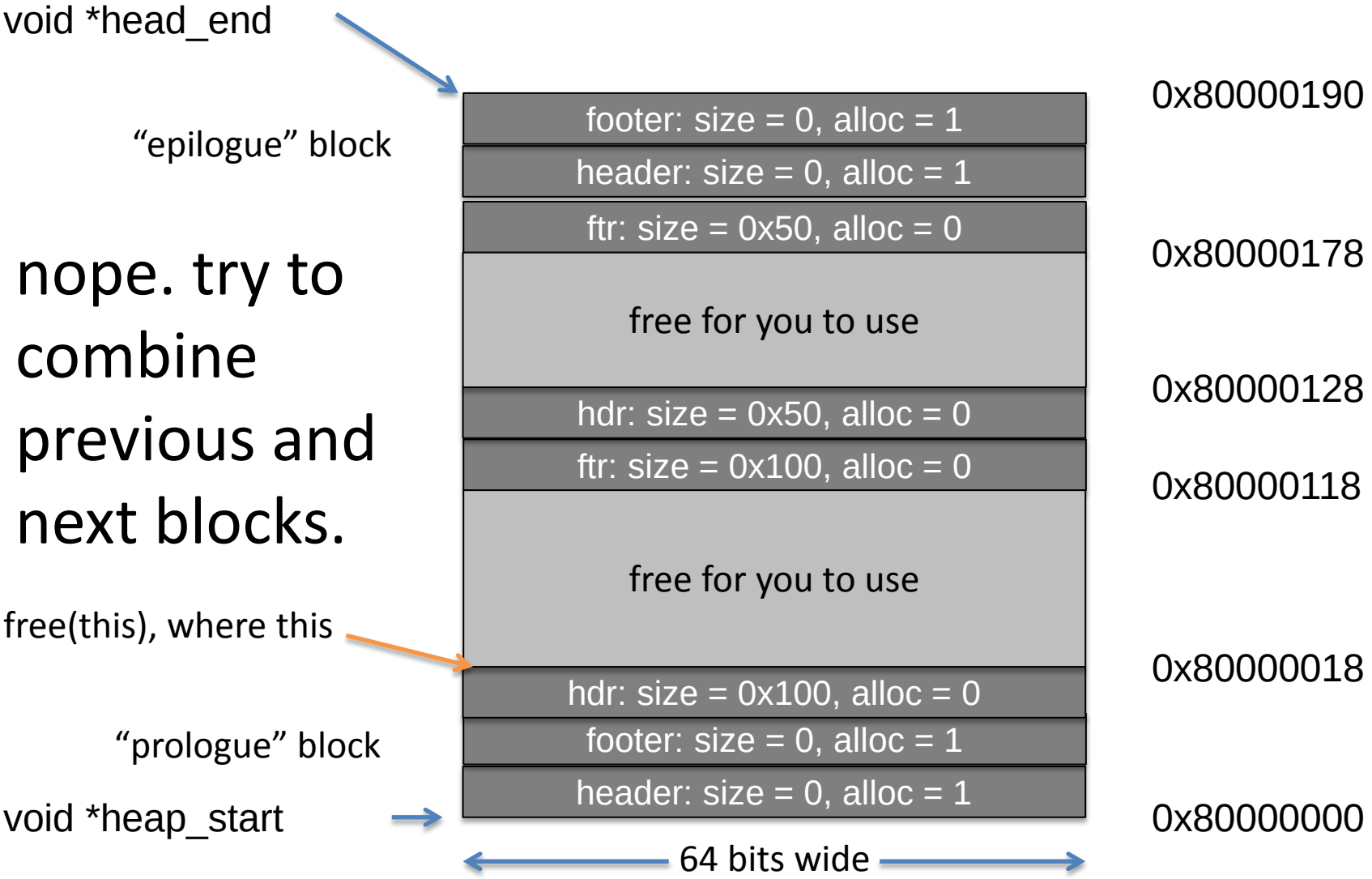


Are we done?

suddenly,free(0x80000018)



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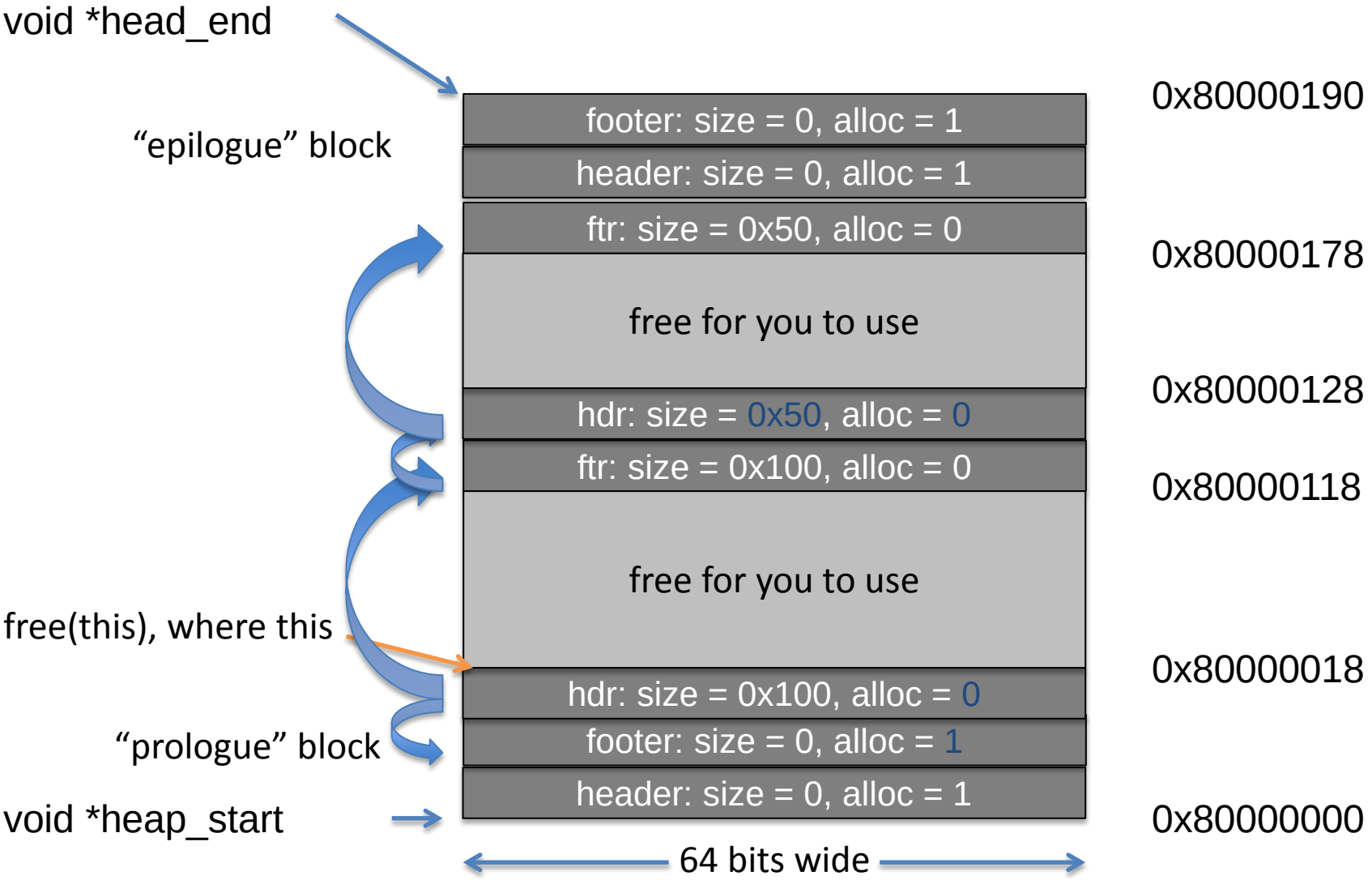

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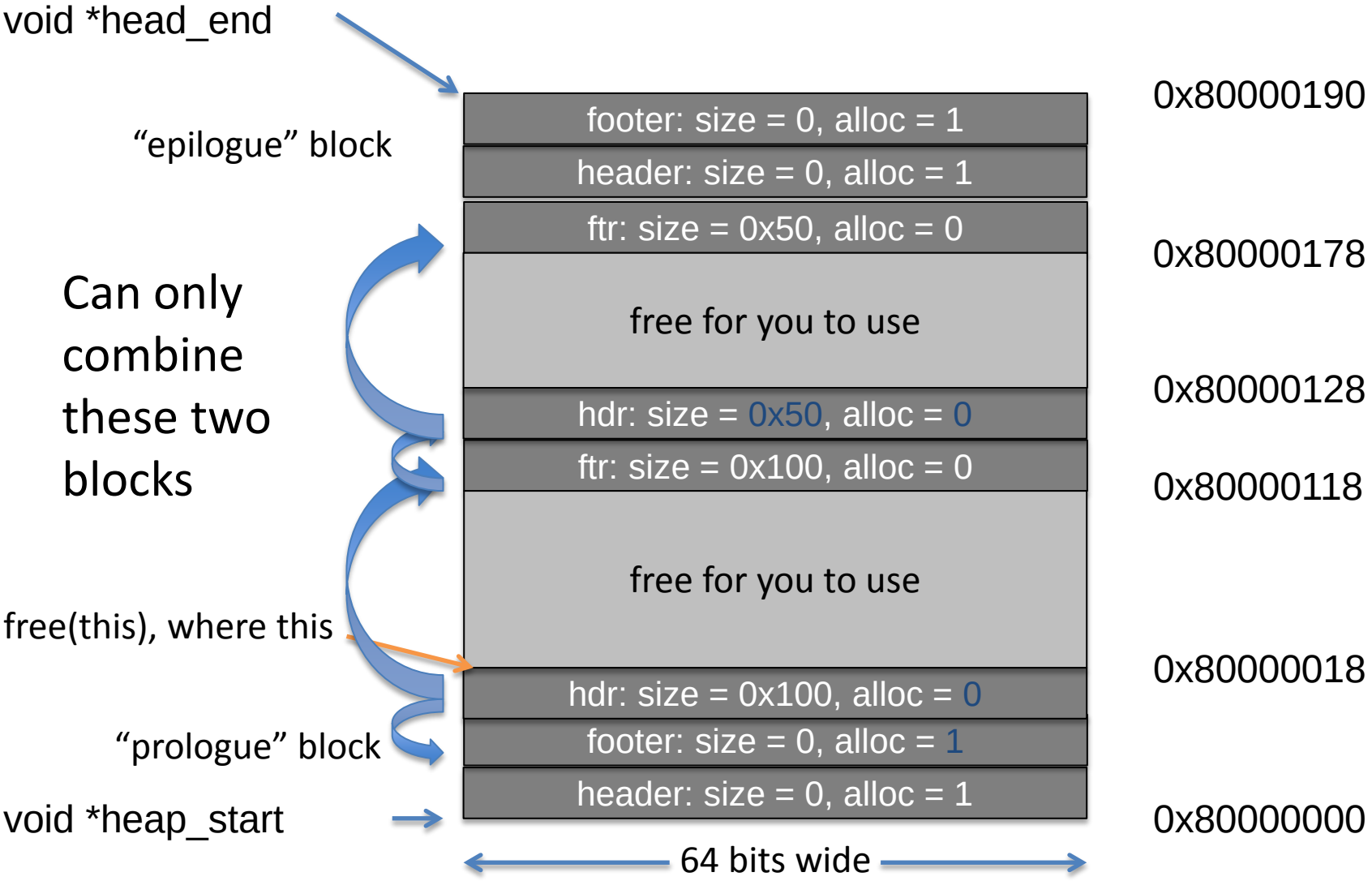

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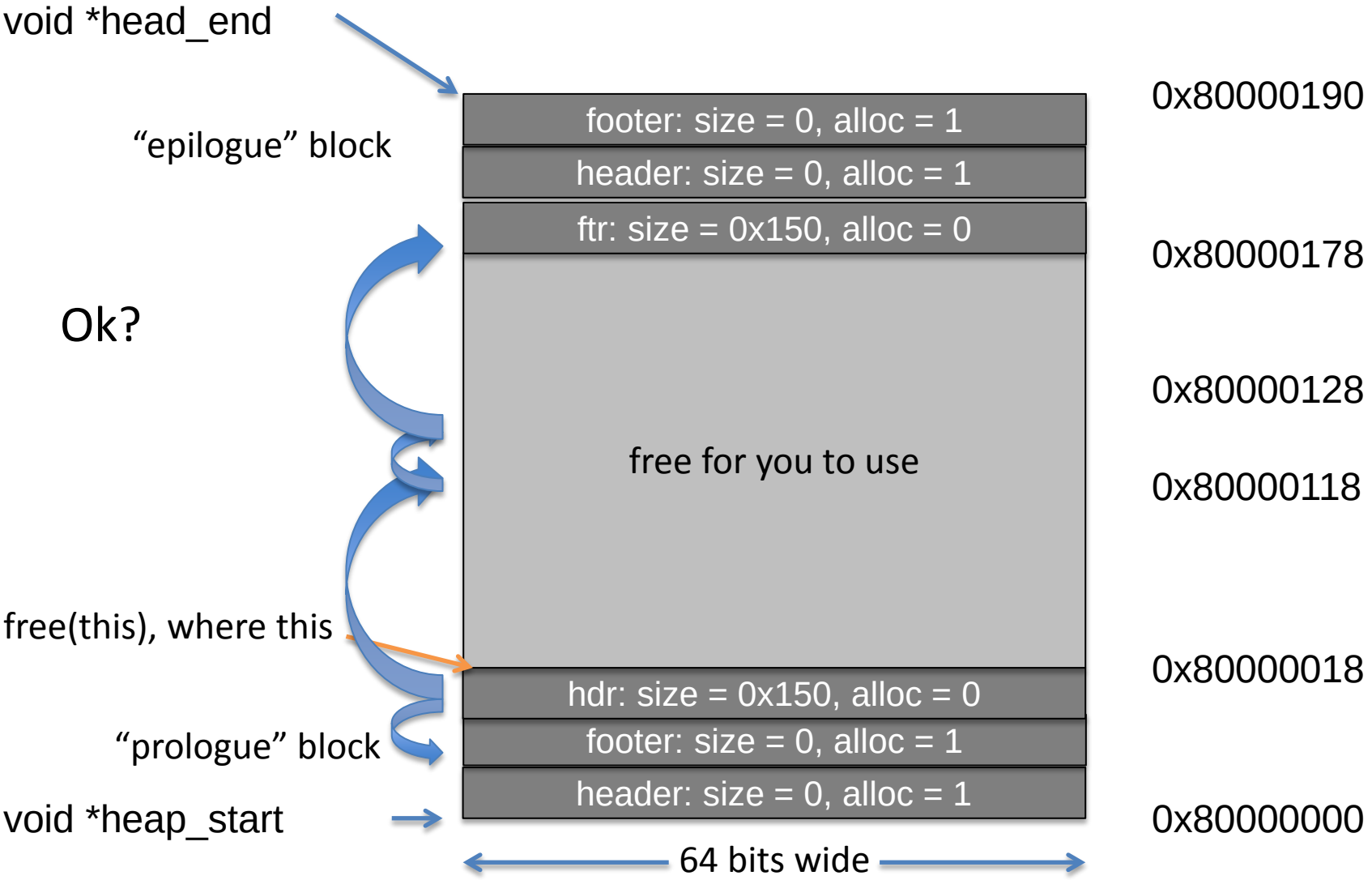

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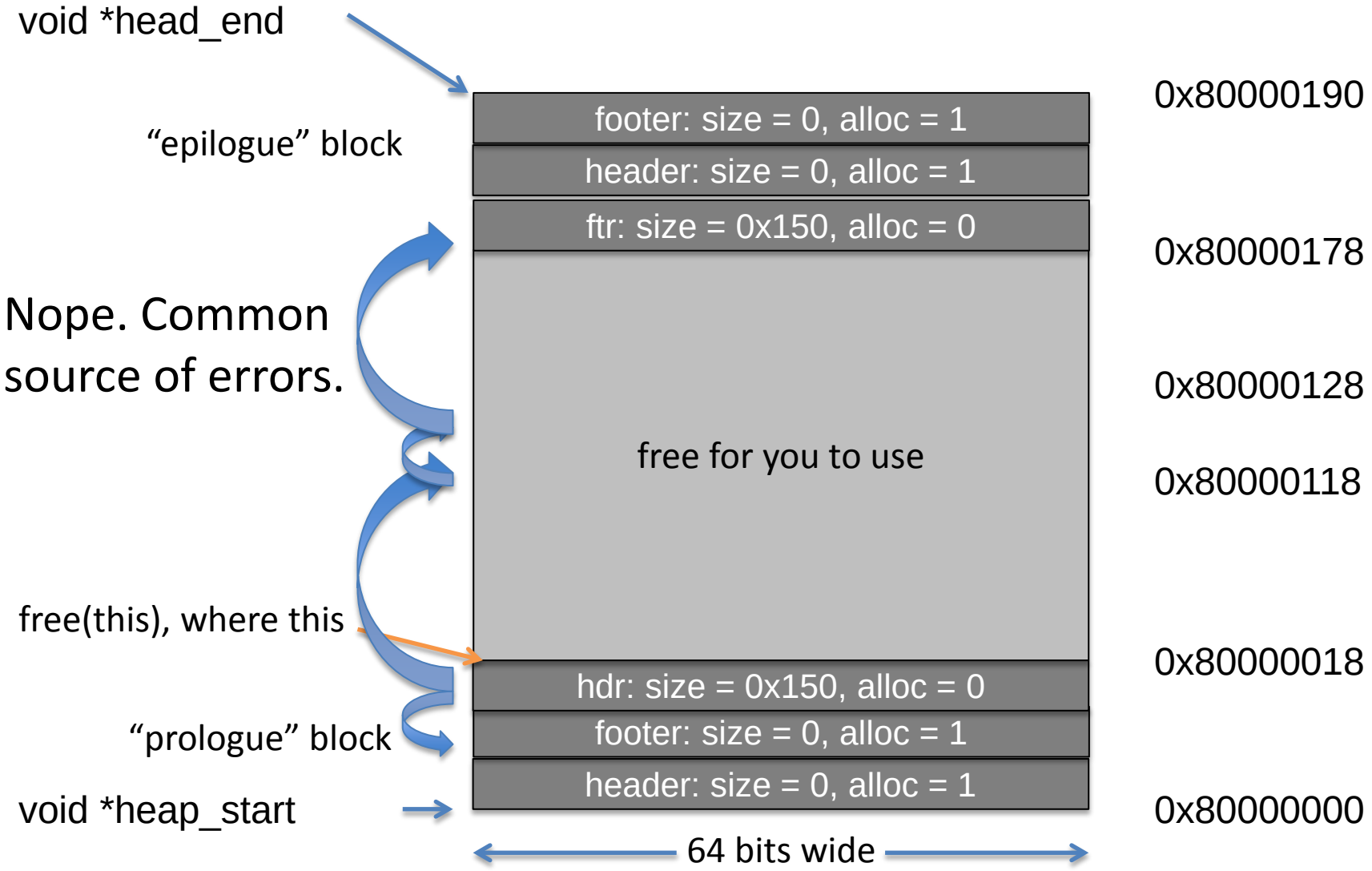

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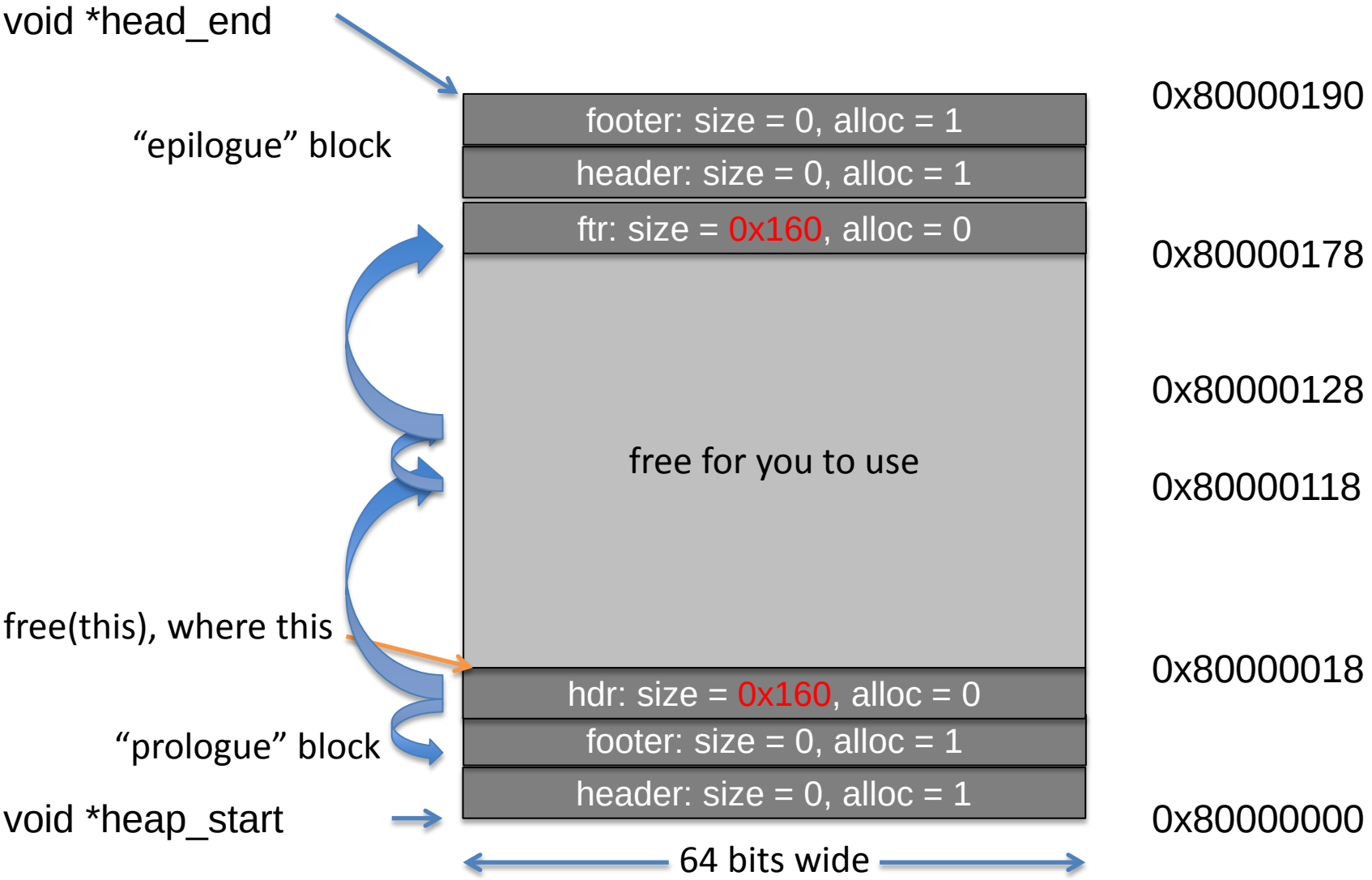

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How to Start (suggestion)

- Read the 32 bit implicit list in your textbook and wade through the sea of macros.
  - Don't copy and paste from the CSAPP website (you won't learn as much).
- Implement a naïve 64 bit implicit list
  - you can leave out coalescing, just for now
- Implement mm_checkheap() for this heap pattern.

How to Finish

- Turn an implicit list into an explicit list
  - update mm_checkheap(), debug, tune
- Turn your explicit list into segregated free lists
  - update mm_checkheap(), debug, tune

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```
[student@makoshark]$ ./mdriver
Using default tracefiles in ./traces/
Measuring performance with a cycle counter.
Processor clock rate ~= 2260.7 MHz
...........................
Results for mm malloc:
  valid  util   ops    secs     Kops  trace
    yes    89%  100000  0.004959 20165 ./traces/alaska.rep
  * yes    75%   11991  0.001168 10266 ./traces/chrome.rep
  u yes    59%      --       --    -- ./traces/exhaust.rep
  * yes    77%     200  0.000015 13613 ./traces/lrucd.rep
  u yes    99%      --       --    -- ./traces/needle.rep
  p yes     --    6495  0.004902  1325 ./traces/seglist.rep
    yes    99%      12  0.000003  4105 ./traces/short2.rep
17 16      85%  149036  0.024727  6027

Perf index = 52 (util) & 11 (thru) = 63/100
```

```
if(size == 213) /* large_trace.rep */
{
    // skip searching through free
    // list, because there isn't any
    // block that fits – I checked
    // the trace.
    extend_heap(size);
}
```

Not a general purpose allocator.

You will be penalized for this.

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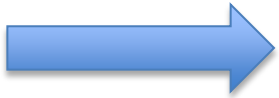
Misc

*p + 0xff | 0x08  SIZE(HD(ptr))

?????

oh.

Misc

#define MAX(x, y) x > y ? x : y

- MAX(x++,y) -> x++ > y ? x++ : y
  - Not what you'd expect

```
static inline int max(x, y) {
   return x > y ? x : y;
}
```

- max(x++, y)?

#define DOUBLE(x) 2 * x

- DOUBLE(x+1) -> 2 * x + 1 (wrong)

#define DOUBLE(x) 2 * (x)

- struct __attribute__ ((__packed__))
  - neat, but gcc specific (not standard)

Debugging Tips, Misc

1. write mm_checkheap().
2. write mm_checkheap() well.
3. write coalescing to make bugs more apparent, fix bugs using mm_checkheap().
4. Start now.
5. Accelerate neutrinos past the speed of light, enabling you to start three days ago.
6. Good luck!