15213 Recitation Section C

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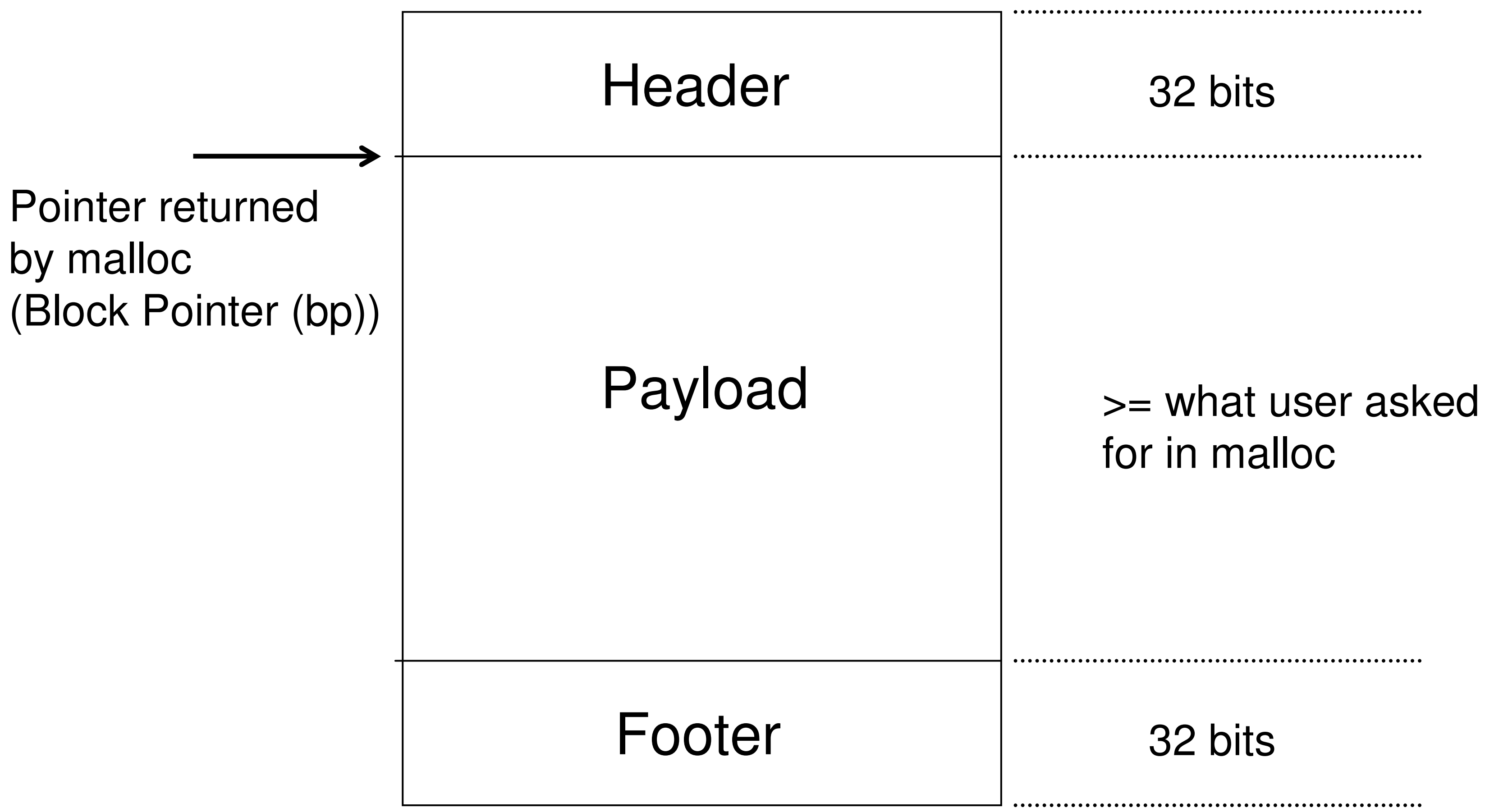
Outline

- Understanding mm-helper.c
- Adding debugging info to mm-helper.c

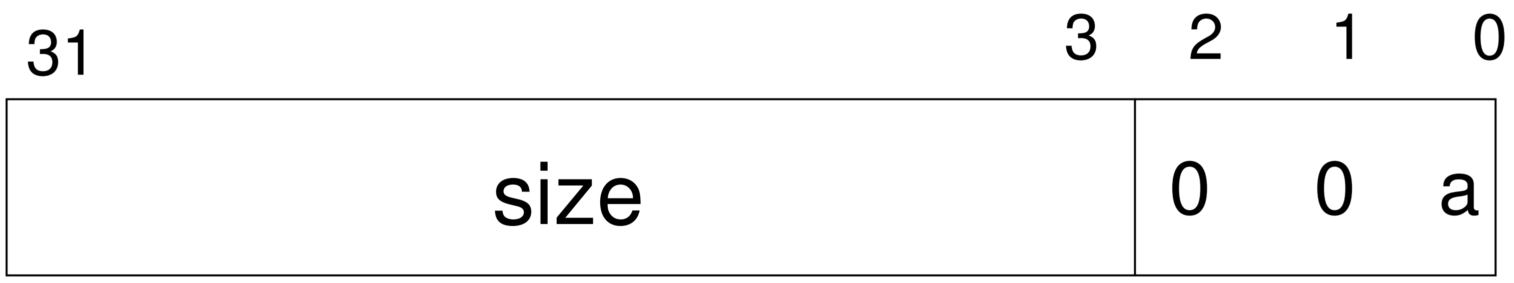
What does mm-helper.c do ?

- Implicit Free List
  - Header with each block – (size / allocated bit)
  - No separate Free List – free blocks linked implicitly by size fields in header
- First Fit
  - Searches free list from beginning and picks first block that is large enough
- Immediate Boundary Tag Coalescing
  - Footer (boundary tag), replica of header

Block Format


Header
32 bits
Pointer returned by malloc (Block Pointer (bp))
Payload
>= what user asked for in malloc
Footer
32 bits

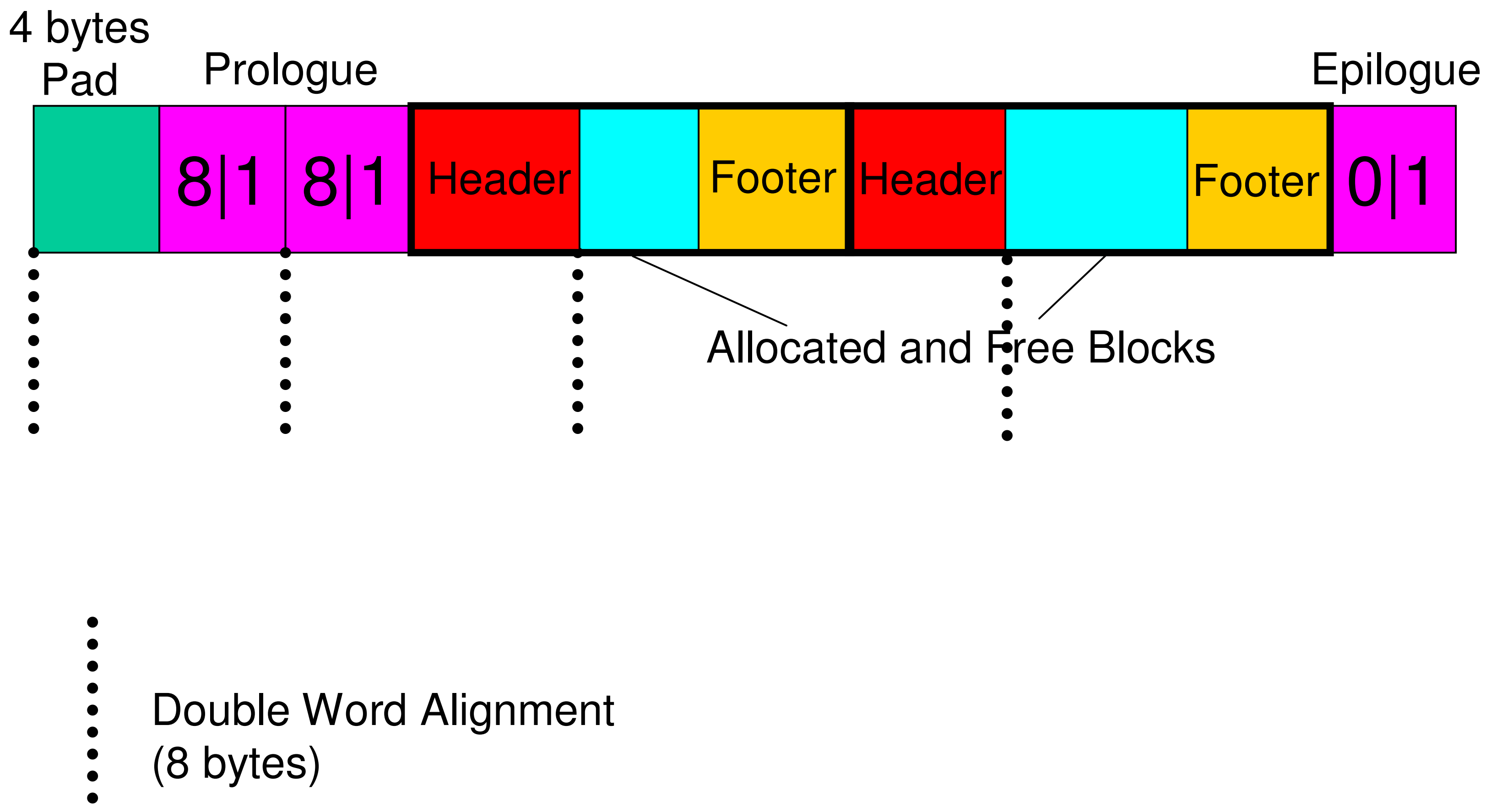
Header/Footer Format



- Double word alignment
  - Three lower-order bits of size always 0
- Pack size and allocated bits into a single integer
  - Size = 24 (0x18). Block is allocated

    Header = 0 x18 | 0x1 = 0x19

Heap Format


4 bytes
Pad
Prologue
8|1
8|1
Header
Footer
Header
Footer
0|1
Epilogue
Allocated and Free Blocks
Double Word Alignment
(8 bytes)

Very Useful Macros

- #define WSIZE 4
- #define DSIZE 8
- #define CHUNKSIZE (1<<12)
- #define OVERHEAD 8

Very Useful Macros

- #define PACK(size, alloc) ((size) | (alloc))
- #define GET(p) (*(size_t *)(p))
- #define PUT(p, val) (*(size_t *)(p) = (val))
- #define GET_SIZE(p) (GET(p) & ~0x7)
- #define GET_ALLOC(p) (GET(p) & 0x1)

Very Useful Macros

- #define HDRP(bp)
  ((char *)(bp) - WSIZE)

- #define FTRP(bp)
  ((char *)(bp) + GET_SIZE(HDRP(bp)) - DSIZE)

- #define NEXT_BLKP(bp)
  ((char *)(bp) + GET_SIZE(((char *)(bp) - WSIZE)))

- #define PREV_BLKP(bp)
  ((char *)(bp) - GET_SIZE(((char *)(bp) - DSIZE)))

Initializing the Heap

```
int mm_init(void) {
   if ((heap_listp = mem_sbrk(4*WSIZE)) == NULL)
      return -1;

   PUT(heap_listp, 0);
   PUT(heap_listp+WSIZE, PACK(OVERHEAD, 1));
   PUT(heap_listp+DSIZE, PACK(OVERHEAD, 1));
   PUT(heap_listp+WSIZE+DSIZE, PACK(0, 1));
   heap_listp += DSIZE;

   if (extend_heap(CHUNKSIZE/WSIZE) == NULL)
      return -1;

   return 0;
 }
```

Extending the Heap

```
static void *extend_heap(size_t words) {
   char *bp;
   size_t size;

   size = (words % 2) ? (words+1)*WSIZE :
                        words*WSIZE;
   if ((int)(bp = mem_sbrk(size)) < 0)
            return NULL;

   PUT(HDRP(bp), PACK(size, 0));
   PUT(FTRP(bp), PACK(size, 0));
   PUT(HDRP(NEXT_BLKP(bp)), PACK(0, 1));

   return coalesce(bp);
 }
```

Malloc

```
void *mm_malloc(size_t size) {
    size_t asize, extendsize;
    char *bp;

    if (size <= 0) return NULL;
    if (size <= DSIZE)
         asize = DSIZE+OVERHEAD;
    else
         asize = DSIZE*((size+(OVERHEAD)+(DSIZE-1))/DSIZE);

    if ((bp = find_fit(asize)) != NULL) {
        place(bp, asize);
        return bp;
    }
    extendsize = MAX(asize,CHUNKSIZE);
    if ((bp = extend_heap(extendsize/WSIZE)) == NULL)
        return NULL;
    place(bp, asize);
    return bp;
}
```

Finding First Fit

```
static void *find_fit(size_t asize) {
    void *bp;

    for (bp = heap_listp; GET_SIZE(HDRP(bp)) > 0;
          bp = NEXT_BLKP(bp))
        if (!GET_ALLOC(HDRP(bp))
         && (asize <= GET_SIZE(HDRP(bp))))
             return bp;

    return NULL;
}
```

Malloc

```
void *mm_malloc(size_t size) {
    size_t asize, extendsize;
    char *bp;

    if (size <= 0) return NULL;
    if (size <= DSIZE)
         asize = DSIZE+OVERHEAD;
    else
         asize = DSIZE*((size+(OVERHEAD)+(DSIZE-1))/DSIZE);

    if ((bp = find_fit(asize)) != NULL) {
        place(bp, asize);         ←
        return bp;
    }
    extendsize = MAX(asize,CHUNKSIZE);
    if ((bp = extend_heap(extendsize/WSIZE)) == NULL)
        return NULL;
    place(bp, asize);
    return bp;
}
```

Placing a Block in a Free Block

```
static void place(void *bp, size_t asize) {
    size_t csize = GET_SIZE(HDRP(bp));

    if ((csize - asize) >= (DSIZE + OVERHEAD)) {
      PUT(HDRP(bp), PACK(asize, 1));
      PUT(FTRP(bp), PACK(asize, 1));
      bp = NEXT_BLKP(bp);
      PUT(HDRP(bp), PACK(csize-asize, 0));
      PUT(FTRP(bp), PACK(csize-asize, 0));
   }
   else {
      PUT(HDRP(bp), PACK(csize, 1));
      PUT(FTRP(bp), PACK(csize, 1));
   }
}
```

Malloc

```
void *mm_malloc(size_t size) {
    size_t asize, extendsize;
    char *bp;

    if (size <= 0) return NULL;
    if (size <= DSIZE)
         asize = DSIZE+OVERHEAD;
    else
         asize = DSIZE*((size+(OVERHEAD)+(DSIZE-1))/DSIZE);

    if ((bp = find_fit(asize)) != NULL) {
        place(bp, asize);
        return bp;
    }
    extendsize = MAX(asize,CHUNKSIZE);
    if ((bp = extend_heap(extendsize/WSIZE)) == NULL)
        return NULL;
    place(bp, asize);
    return bp;
}
```

Free

```
void mm_free(void *bp) {
   size_t size = GET_SIZE(HDRP(bp));

   PUT(HDRP(bp), PACK(size, 0));
   PUT(FTRP(bp), PACK(size, 0));

   coalesce(bp);
}
```

Coalesce: Called by mm_free() & extend_heap()

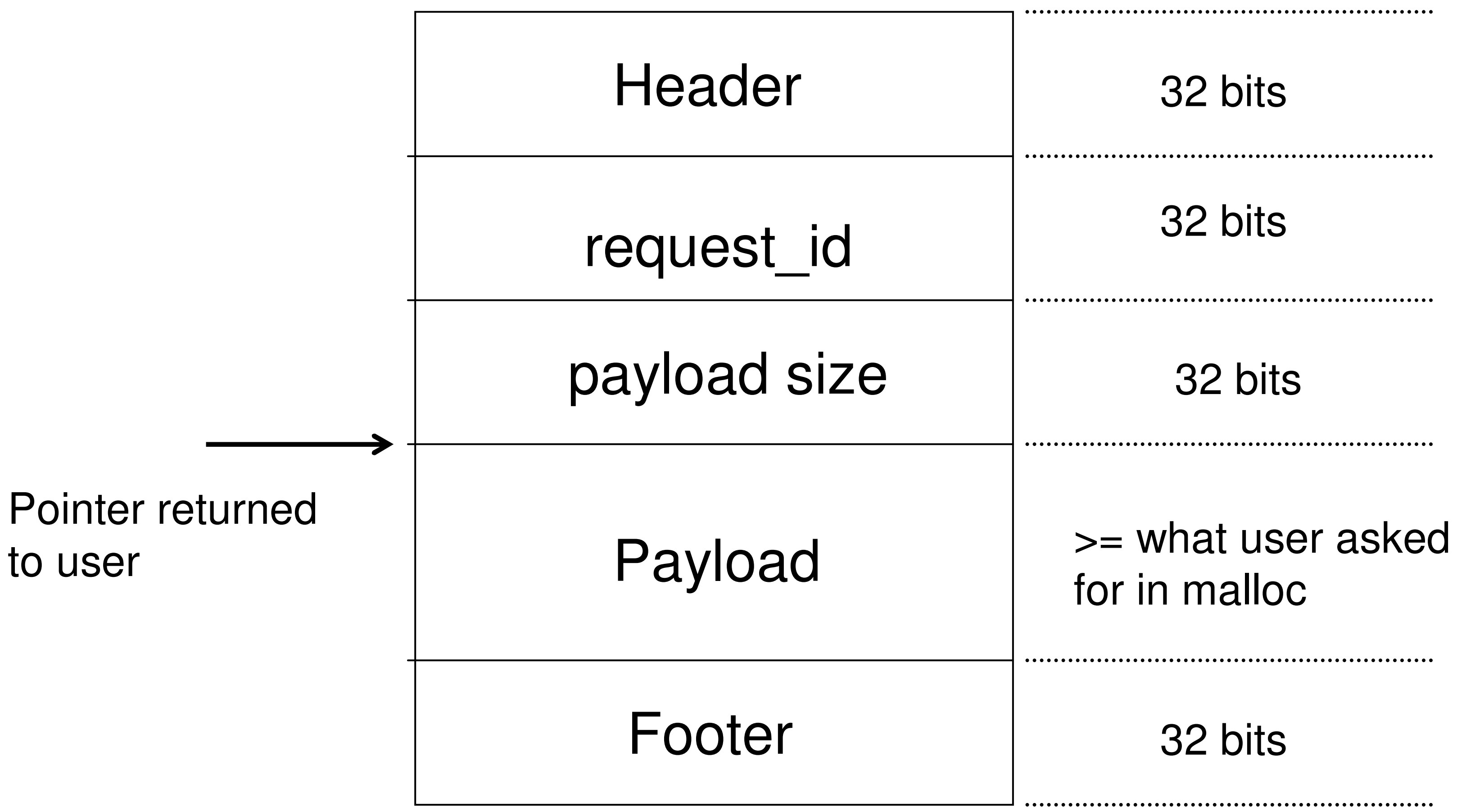
```
static void *coalesce(void *bp) {
    size_t prev_alloc = GET_ALLOC(FTRP(PREV_BLKP(bp)));
    size_t next_alloc = GET_ALLOC(HDRP(NEXT_BLKP(bp)));
    size_t size = GET_SIZE(HDRP(bp));

    if (prev_alloc && next_alloc) { return bp;  }
    else if (prev_alloc && !next_alloc) { …. . }
    else if (!prev_alloc && next_alloc) {
        size += GET_SIZE(HDRP(PREV_BLKP(bp)));
        PUT(FTRP(bp), PACK(size, 0));
        PUT(HDRP(PREV_BLKP(bp)), PACK(size, 0));
        bp = PREV_BLKP(bp);
    }
    else { ……. }
    return bp;
}
```

Adding Debugging Information

- mm_heapcheck
- Display "request_id" and "payload" of every active block
  - request_id : malloc request counter (0..
    - mm_init sets the counter to 0
    - mm_malloc increments the counter
  - payload size : the memory requested by malloc
    - Can be different from the allocated size!!!
- We need to store the info somewhere ?

Allocated Block Format



One Way to Implement This

- Inside malloc
  - Allocate additional memory in malloc

```
PUT(bp,request_counter);
PUT(bp+4,size);
return bp+DSIZE;
```

- Inside Free
  - bp = bp – DSIZE;

Heapcheck

- Put all sorts of sanity checks
- Scan the implicit list
  - like the first fit function
  - print request_id and size

Explicit Lists

- Separate Free List
  - Can find a free block quickly
- Change Free Block Format
  - Add prev pointer
  - Add next pointer
- Where to store free list pointer
  - Only one WORD
  - Can store in unused PAD word
- Some functions to add
  - static void insertfree_block(void * freeblkptr);
  - static void removefree_block(void * freeblkptr);