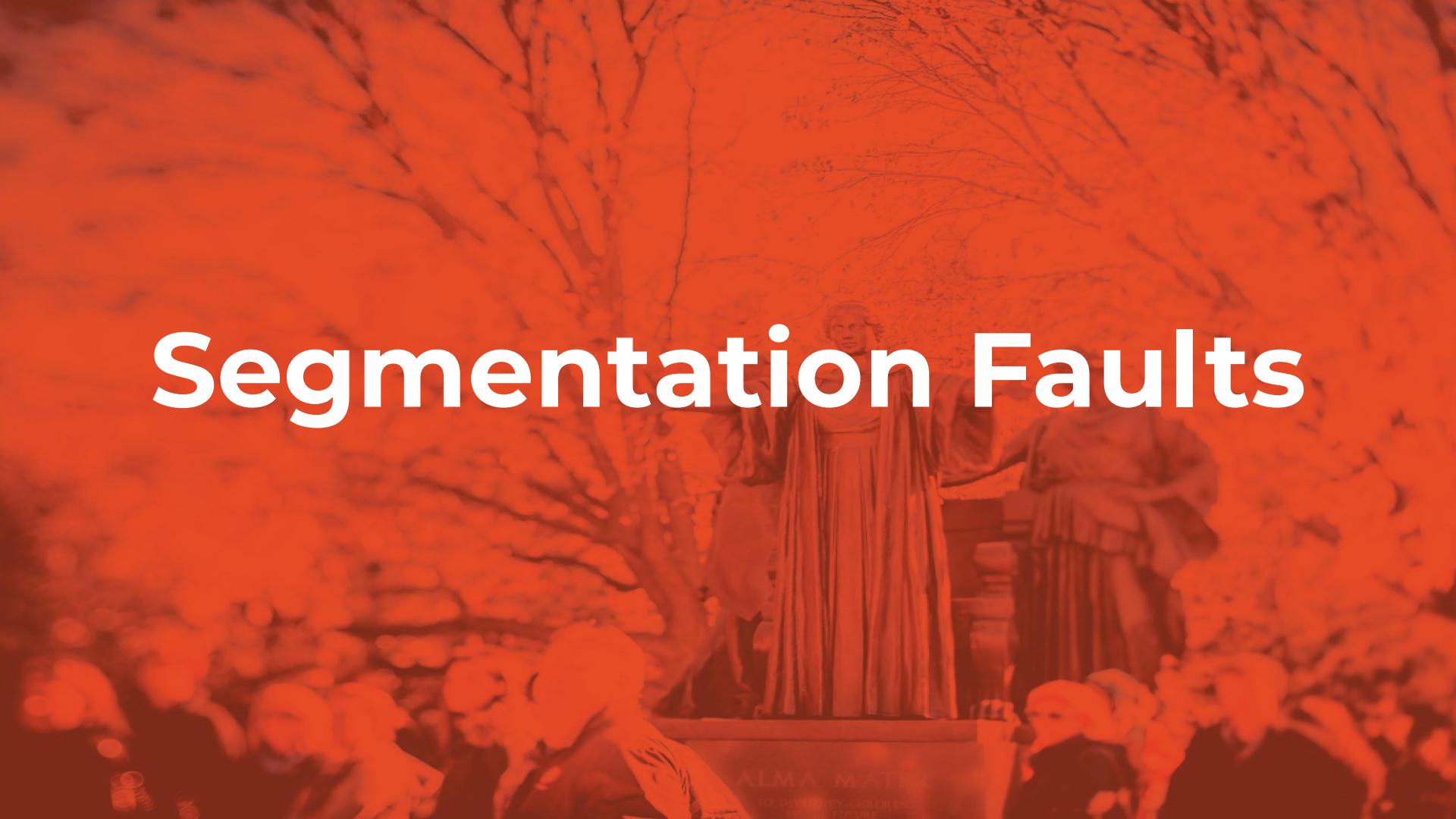
# Page Eviction, Replacement, Heap Management

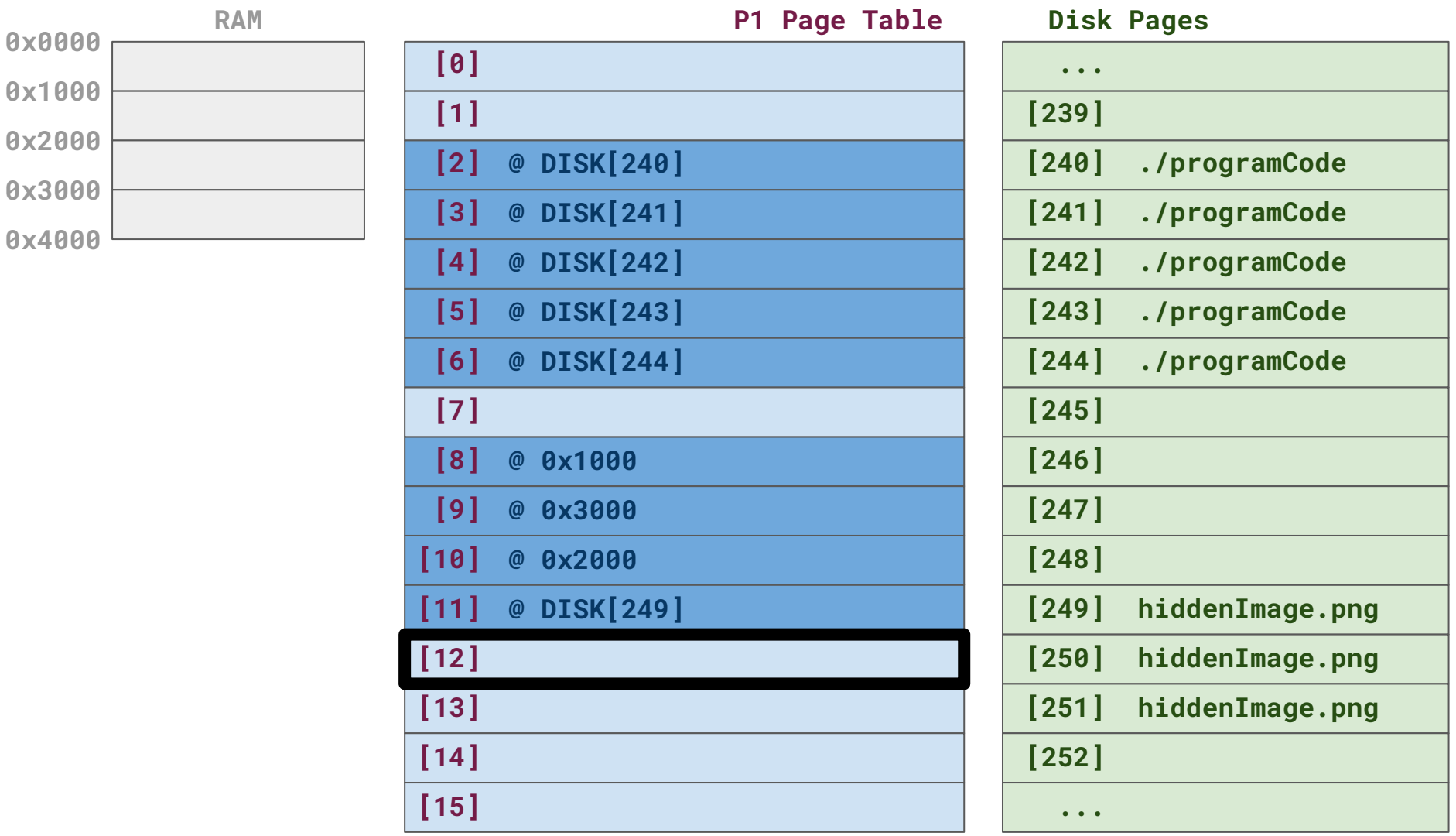
**CS 240 - The University of Illinois**

Wade Fagen-Ulmschneider

September 9, 2021




# Segmentation Faults


RAM
0x0000
0x1000
0x2000
0x3000
0x4000
P1 Page Table
[0]
[1]
[2] @ DISK[240]
[3] @ DISK[241]
[4] @ DISK[242]
[5] @ DISK[243]
[6] @ DISK[244]
[7]
[8] @ 0x1000
[9] @ 0x3000
[10] @ 0x2000
[11] @ DISK[249]
[12]
[13]
[14]
[15]
Disk Pages
...
[239]
[240] ./programCode
[241] ./programCode
[242] ./programCode
[243] ./programCode
[244] ./programCode
[245]
[246]
[247]
[248]
[249] hiddenImage.png
[250] hiddenImage.png
[251] hiddenImage.png
[252]
...

# Page Eviction and Replacement Strategies

# Page Eviction and Replacement

When we need to remove a page from RAM and store it on disk, **how do we decide which page to remove given a page access pattern**?

# Strategy:

| Access:<br>RAM | 17 | 33 | 40 | 17 | 43 | 8 | 99 | 33 | 99 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|
| [0] | | | | | | | | | | |
| [1] | | | | | | | | | | |
| [2] | | | | | | | | | | |
| [3] | | | | | | | | | | |

# Strategy:

| Access:<br>RAM | 17 | 33 | 40 | 17 | 43 | 8 | 99 | 33 | 99 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|
| [0] | | | | | | | | | | |
| [1] | | | | | | | | | | |
| [2] | | | | | | | | | | |
| [3] | | | | | | | | | | |

# Strategy:

| Access:<br>RAM | 17 | 33 | 40 | 17 | 43 | 8 | 99 | 33 | 99 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|
| [0] | | | | | | | | | | |
| [1] | | | | | | | | | | |
| [2] | | | | | | | | | | |
| [3] | | | | | | | | | | |

# Strategy:

| Access:<br>RAM | 17 | 33 | 40 | 17 | 43 | 8 | 99 | 33 | 99 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|
| [0] | | | | | | | | | | |
| [1] | | | | | | | | | | |
| [2] | | | | | | | | | | |
| [3] | | | | | | | | | | |

# Other Strategies:

# Heap and Stack Memory

# 06-see-heap-and-stack-usage.c

```
5   int val;
6   printf("&val: %p\n", &val);
7
8   int *ptr = malloc(sizeof(int));
9   printf("&ptr: %p\n", &ptr);
10  printf(" ptr: %p\n", ptr);
11
12  int *ptr2 = malloc(sizeof(int));
13  printf("&ptr2: %p\n", &ptr2);
14  printf(" ptr2: %p\n", ptr2);
15
16  return 0;
```

# Exploration of Efficient Use of Heap Memory

# 06-heap-example.c

```
5   int *a = malloc(4096);
6   printf("a = %p\n", a);
7   free(a);
8
9   int *b = malloc(4096);
10  printf("b = %p\n", b);
11
12  int *c = malloc(4096);
13  printf("c = %p\n", c);
14
15  int *d = malloc(4096);
16  printf("d = %p\n", d);
17
18  free(b);
19  free(c);
20
21  int *e = malloc(5000);
22  printf("e = %p\n", e);
23
24  int *f = malloc(10);
25  printf("f = %p\n", f);
26
27  int *g = malloc(10);
28  printf("g = %p\n", g);
```

# 06-heap-example.c

```
5   int *a = malloc(4096);
6   printf("a = %p\n", a);
7   free(a);
8
9   int *b = malloc(4096);
10  printf("b = %p\n", b);
11
12  int *c = malloc(4096);
13  printf("c = %p\n", c);
14
15  int *d = malloc(4096);
16  printf("d = %p\n", d);
17
18  free(b);
19  free(c);
20
21  int *e = malloc(5000);
22  printf("e = %p\n", e);
23
24  int *f = malloc(10);
25  printf("f = %p\n", f);
26
27  int *g = malloc(10);
28  printf("g = %p\n", g);
```

# 06-heap-example.c

```
5   int *a = malloc(4096);
6   printf("a = %p\n", a);
7   free(a);
8
9   int *b = malloc(4096);
10  printf("b = %p\n", b);
11
12  int *c = malloc(4096);
13  printf("c = %p\n", c);
14
15  int *d = malloc(4096);
16  printf("d = %p\n", d);
17
18  free(b);
19  free(c);
20
21  int *e = malloc(5000);
22  printf("e = %p\n", e);
23
24  int *f = malloc(10);
25  printf("f = %p\n", f);
26
27  int *g = malloc(10);
28  printf("g = %p\n", g);
```

# Heap Management Strategies

# Heap Management Strategies

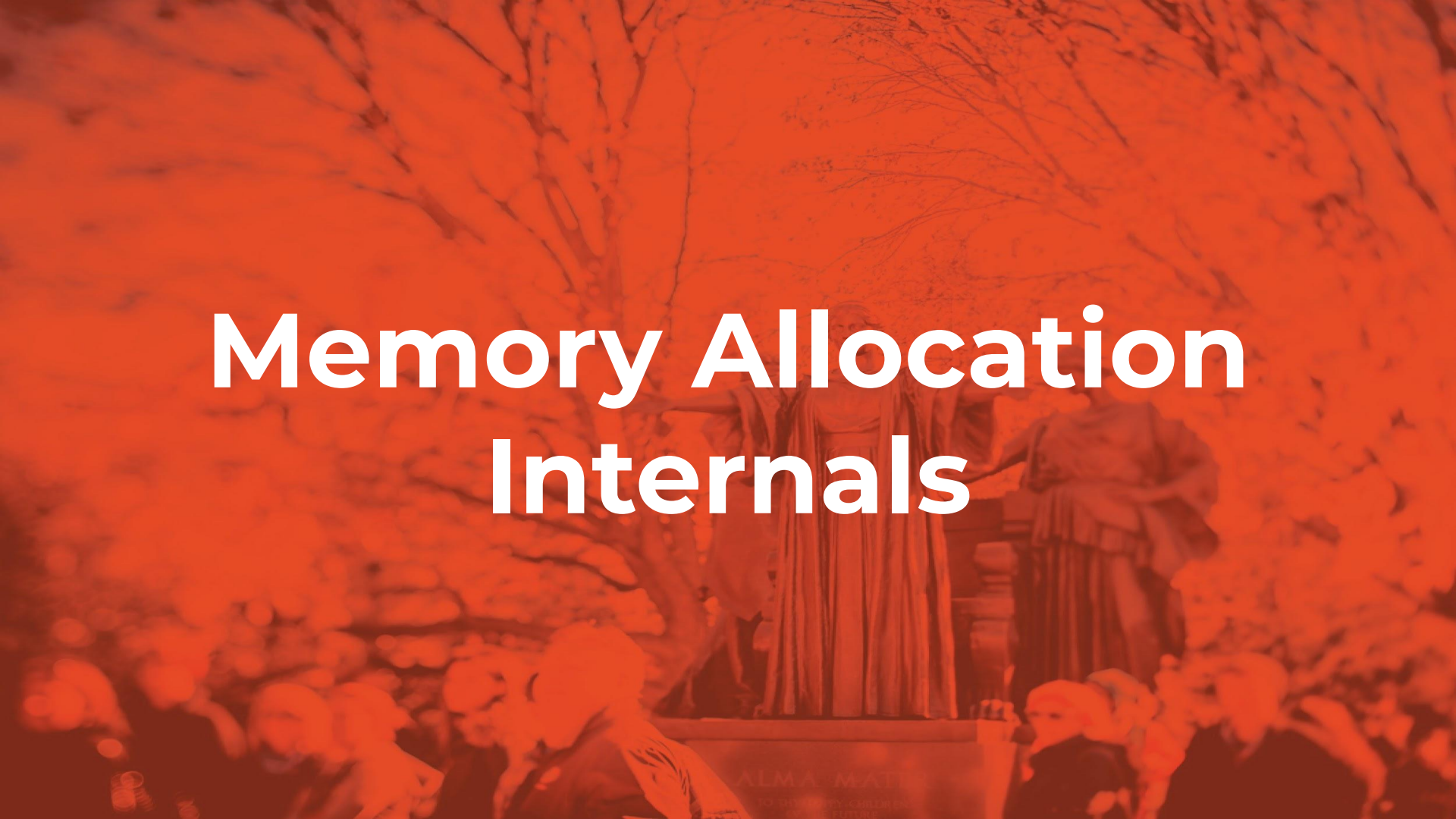
[No Reuse]:

# Heap Management Strategies

[Free Lists]:

# Heap Management Strategies

Free Lists Strategies:



# Memory Allocation Internals

# Heap Management Strategies

Initial Heap Size:

```
void *sbrk(intptr_t increment);
```

> **brk()** and **sbrk()** change the location of the program break, which defines the end of the process's data segment (i.e., the program break is the first location after the end of the uninitialized data segment). Increasing the program break has the effect of allocating memory to the process; decreasing the break deallocates memory.

# 06-heap-example.c

```
5   int *a = malloc(4096);
6   printf("a = %p\n", a);
7   free(a);
8
9   int *b = malloc(4096);
10  printf("b = %p\n", b);
11
12  int *c = malloc(4096);
13  printf("c = %p\n", c);
14
15  int *d = malloc(4096);
16  printf("d = %p\n", d);
17
18  free(b);
19  free(c);
20
21  int *e = malloc(5000);
22  printf("e = %p\n", e);
23
24  int *f = malloc(10);
25  printf("f = %p\n", f);
26
27  int *g = malloc(10);
28  printf("g = %p\n", g);
```