Chapter 14. Memory API

Operating System: Three Easy Pieces

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Slides adapted from Dr. Youjip Won

Memory API: malloc()

```
#include <stdlib.h>

void* malloc(size_t size)
```

- Allocate a memory region on the heap.
  - Argument
    - `size_t size` : size of the memory block(in bytes)
    - `size_t` is an unsigned integer type.
  - Return
    - Success : a void type pointer to the memory block allocated by `malloc`
    - Fail : a null pointer

sizeof()

- Routines and macros are utilized for `size` in `malloc` instead typing in a number directly.
- Two types of results of `sizeof` with variables
  - The actual size of `'x'` is known at run-time.

```
int *x = malloc(10 * sizeof(int));
printf("%d\n", sizeof(x));
```

```
4
```

  - The actual size of `'x'` is known at compile-time.

```
int x[10];
printf("%d\n", sizeof(x));
```

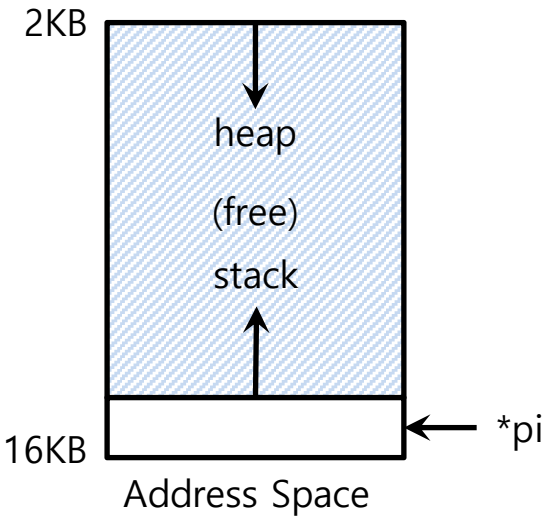
```
40
```

Memory API: free()

```
#include <stdlib.h>

void free(void* ptr)
```

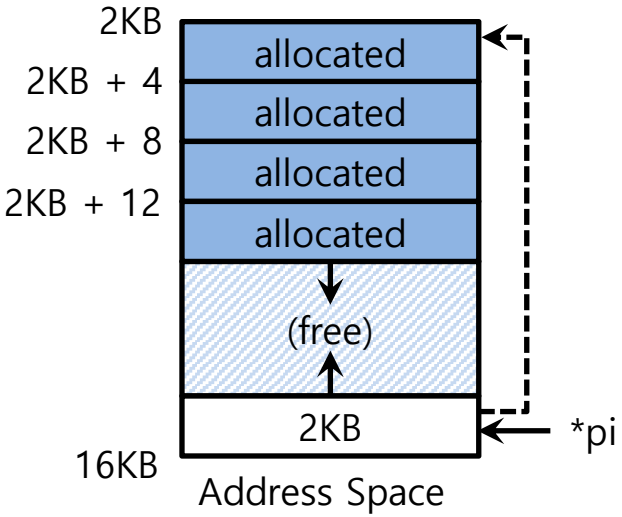
- Free a memory region allocated by a call to `malloc`.
  - Argument
    - `void *ptr` : a pointer to a memory block allocated with `malloc`
  - Return
    - none

Memory Allocating



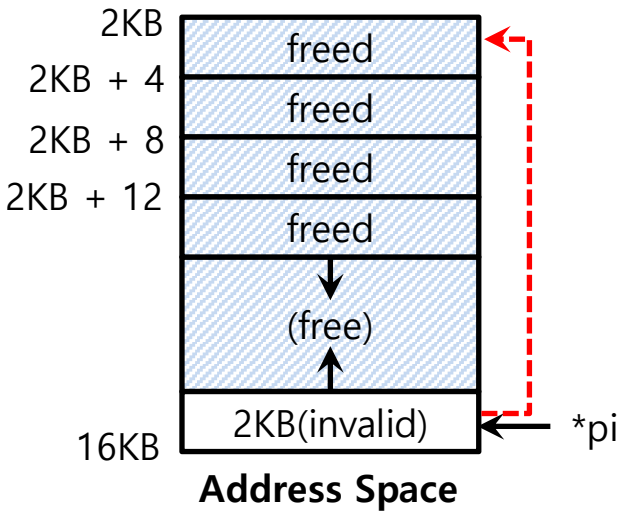
pointer

```
int *pi; // local variable
```

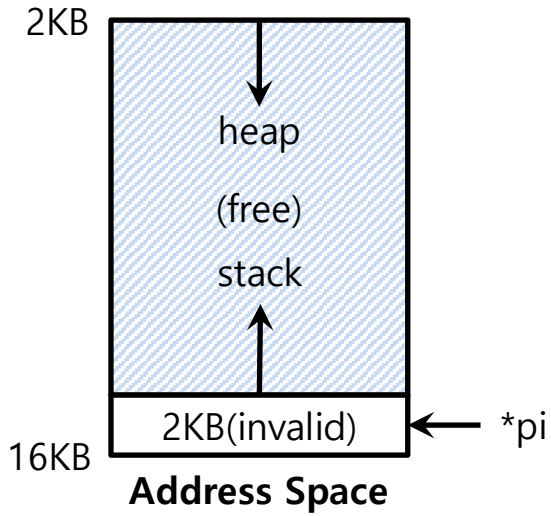



```
pi = (int *)malloc(sizeof(int)* 4);
```

Memory Freeing



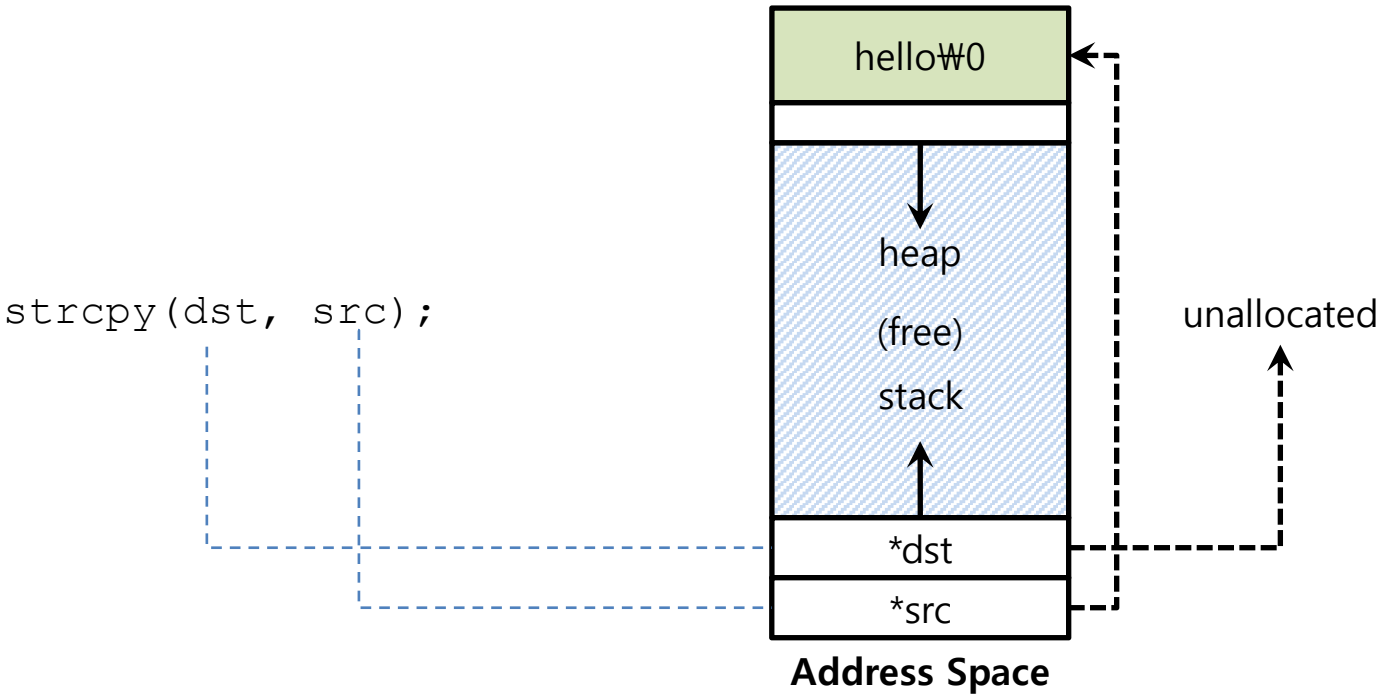

```
free(pi);
```



Forgetting To Allocate Memory

- Incorrect code

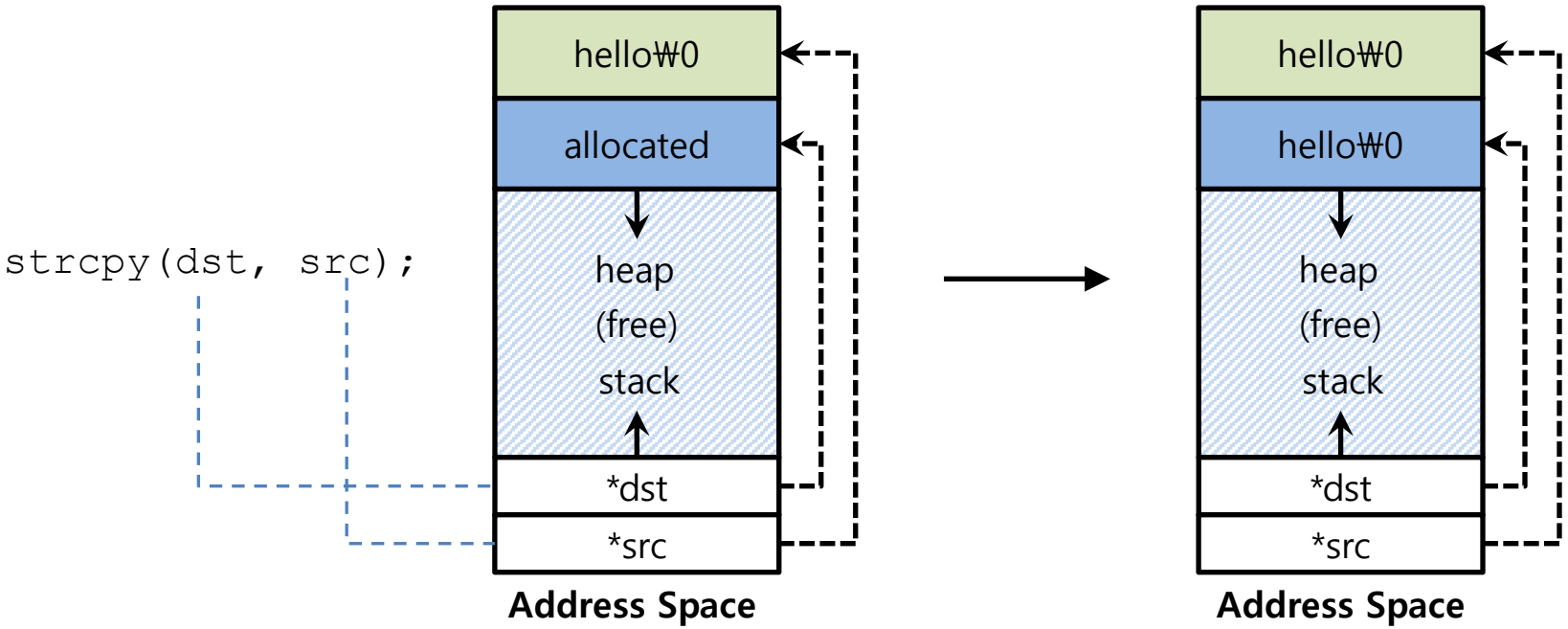
```
char *src = "hello"; //character string constant
char *dst;           //unallocated
strcpy(dst, src);    //segfault and die
```



Forgetting To Allocate Memory(Cont.)

- Correct code

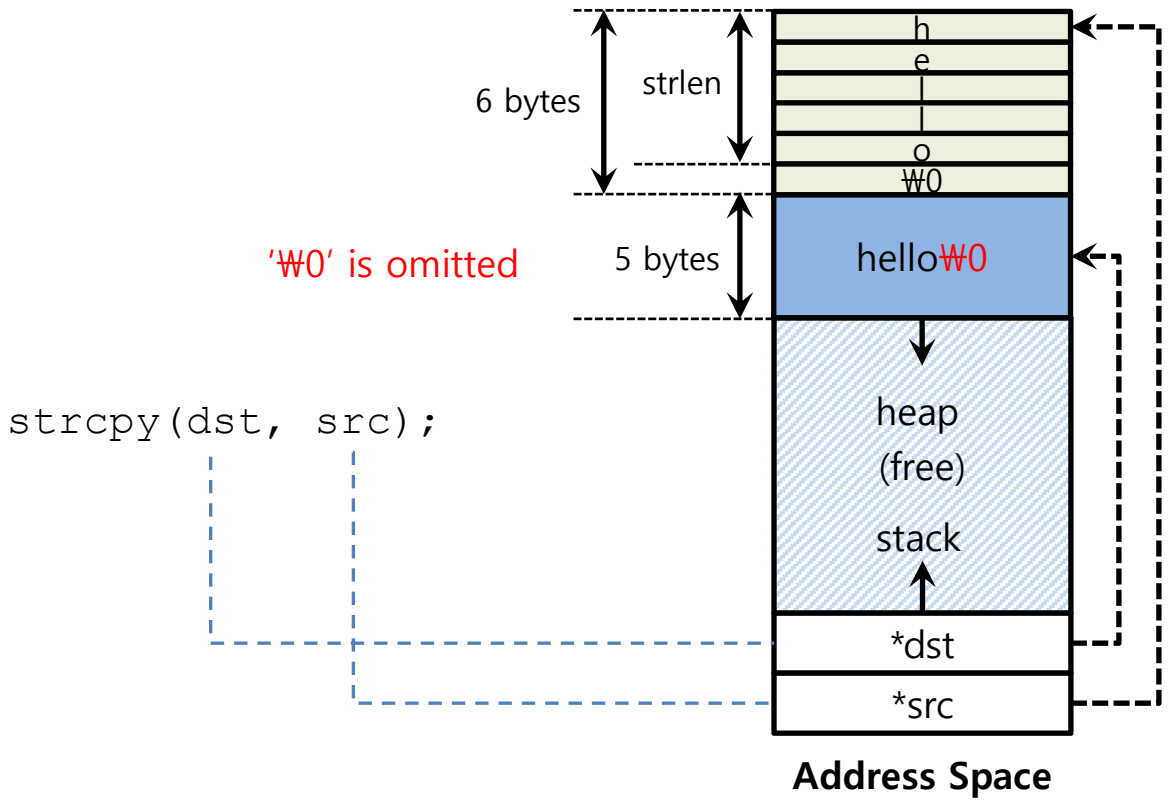
```
char *src = "hello";   //character string constant
char *dst (char *)malloc(strlen(src) + 1 ); // allocated
strcpy(dst, src);      //work properly
```



Not Allocating Enough Memory

- Incorrect code, but work properly

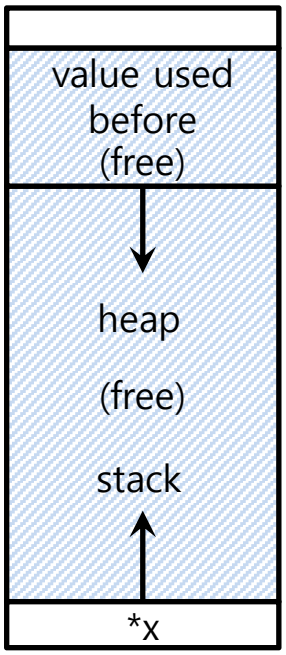
```
char *src = "hello"; //character string constant
char *dst (char *)malloc(strlen(src)); // too small
strcpy(dst, src);    //work properly
```



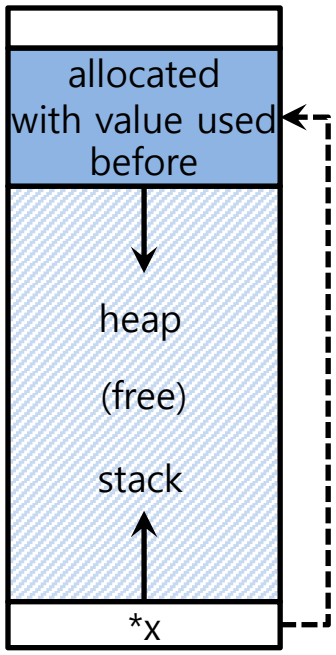
Forgetting to Initialize

- Encounter an uninitialized read

```
int *x = (int *)malloc(sizeof(int)); // allocated
printf("*x = %d\n", *x); // uninitialized memory access
```



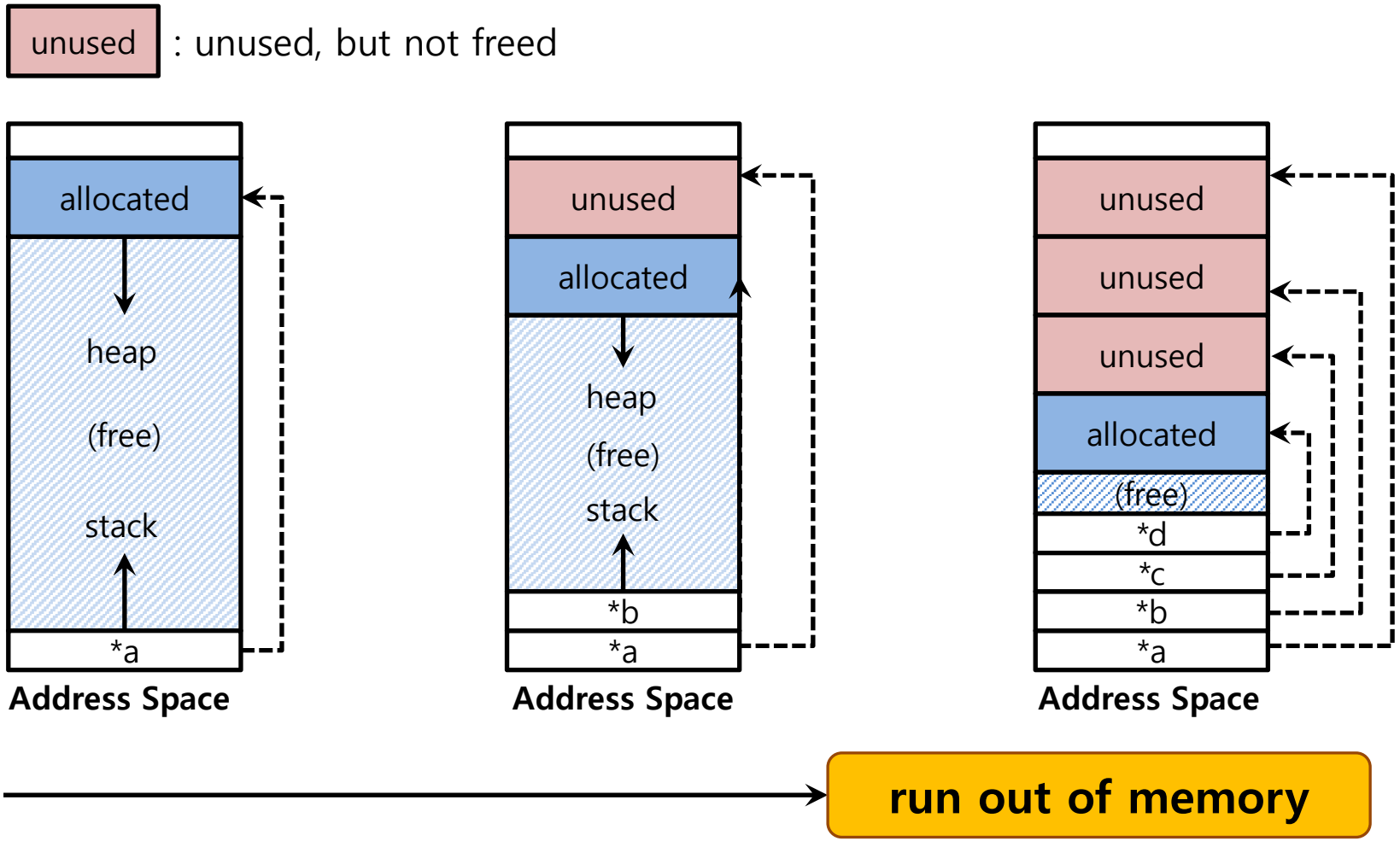
Address Space



Address Space

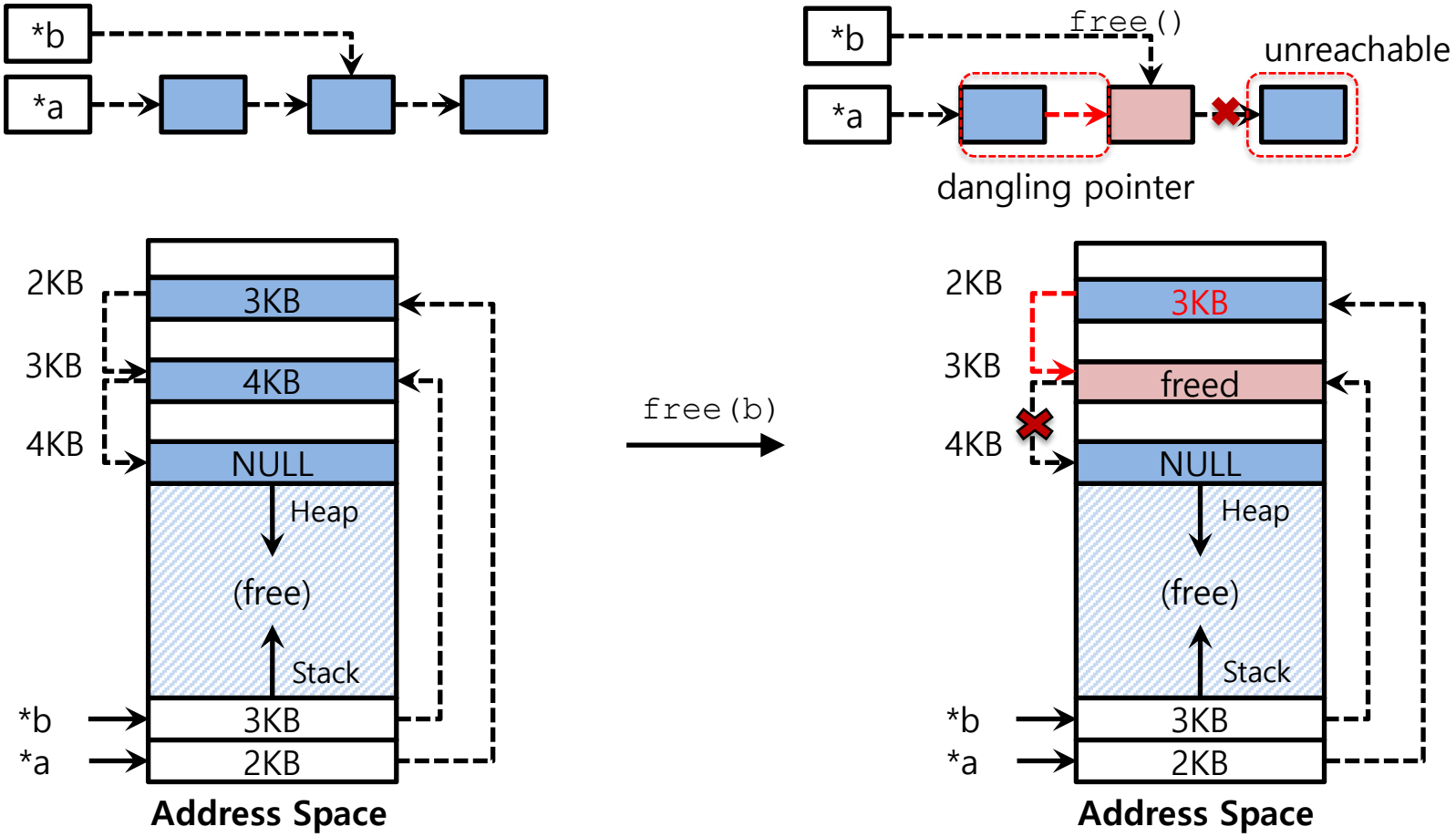
Memory Leak

- A program runs out of memory and eventually dies.



Dangling Pointer

- Freeing memory before it is finished using
  - A program accesses to memory with an invalid pointer



Other Memory APIs: calloc()

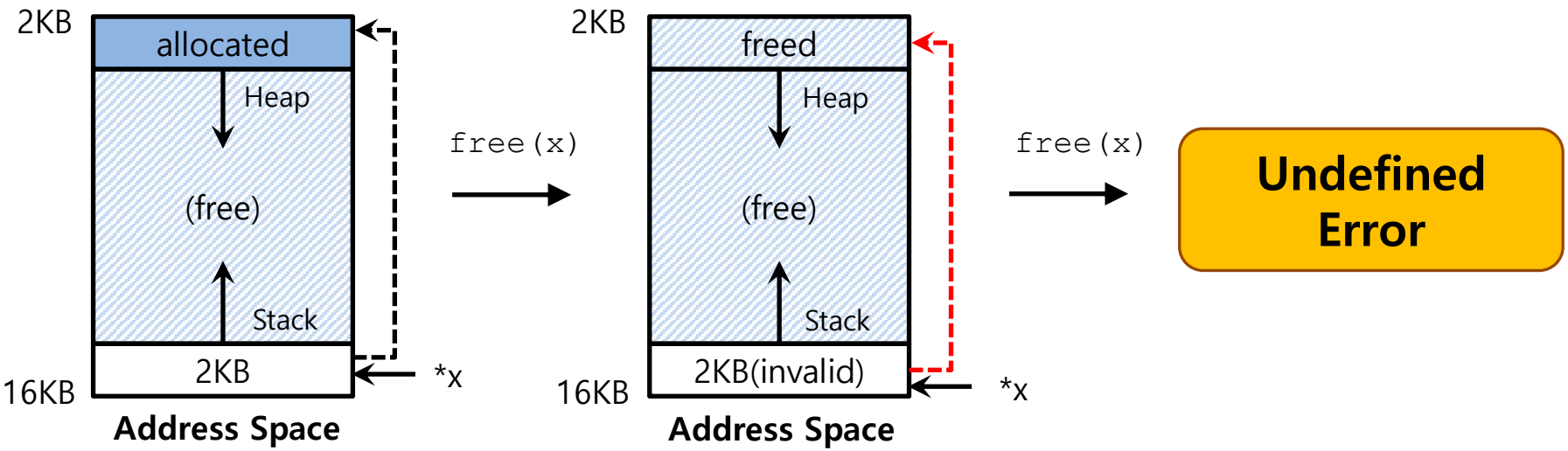
```
#include <stdlib.h>

void *calloc(size_t num, size_t size)
```

- Allocate memory on the heap and zeroes it before returning.
  - Argument
    - `size_t num` : number of blocks to allocate
    - `size_t size` : size of each block(in bytes)
  - Return
    - Success : a void type pointer to the memory block allocated by `calloc`
    - Fail : a null pointer

Double Free

- Free memory that was freed already.

```
int *x = (int *)malloc(sizeof(int)); // allocated
free(x); // free memory
free(x); // free repeatedly
```



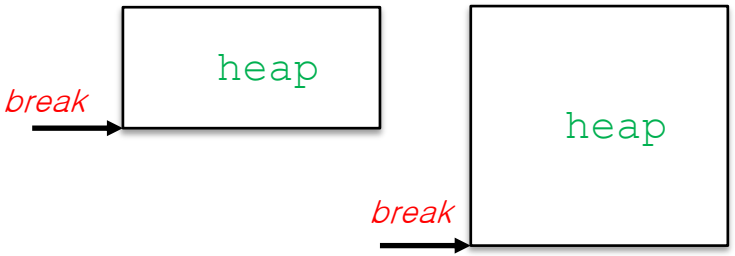
Other Memory APIs: realloc()

```
#include <stdlib.h>

void *realloc(void *ptr, size_t size)
```

- Change the size of memory block.
  - A pointer returned by `realloc` may be either the same as `ptr` or a new.
  - Argument
    - `void *ptr`: Pointer to memory block allocated with `malloc`, `calloc` or `realloc`
    - `size_t size`: New size for the memory block(in bytes)
  - Return
    - Success: Void type pointer to the memory block
    - Fail : Null pointer

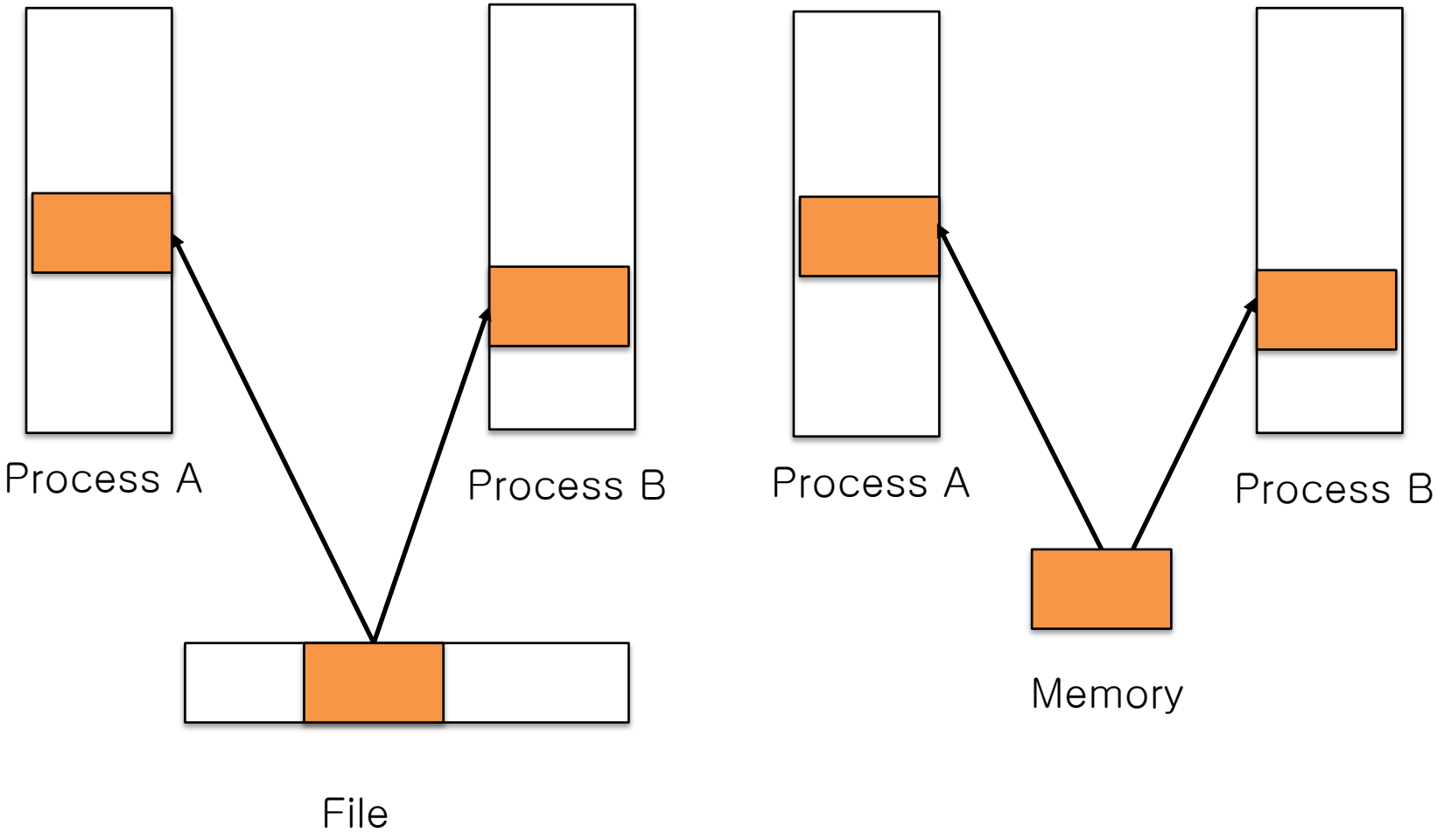
System Calls

```
#include <unistd.h>

int brk(void *addr)
void *sbrk(intptr_t increment);
```



- `malloc` library call use `brk` system call.
  - `brk` is called to expand the program's *break*.
    - *break*: The location of **the end of the heap** in address space
  - `sbrk` is an additional call similar with `brk`.
    - `Sbrk adjusts the program break value by adding a possibly negative size`
    - `brk is used to set the break value to the value of a pointer`
  - Programmers **should never directly call** either `brk` or `sbrk`.

Sharing memory between two Processes



System Calls(Cont.)

```
#include <sys/mman.h>

void *mmap(void *start, size_t length, int port, int flags,
int fd, off_t offset)
```

- mmap maps length bytes starting at offset *offset* from the file specified by the fd into memory, preferably at address *start*.
- *start* address is a hint only, and is usually specified as 0. The actual place where the object is mapped is returned.
- mmap system call can create **an anonymous** memory region.
  - The mapping is not backed by any file; the *fd* and *offset* arguments are ignored.
  - Set *flags* to be MAP_ANONYMOUS
  - The use of this flag in conjunction with **MAP_SHARED** is only supported on Linux since kernel 2.4.