CS107, Lecture 11 Extras
Stack and Heap

Reading: K&R 5.6-5.9 or Essential C section 6 on the heap
Ed Discussion: https://edstem.org/us/courses/28214/discussion/1984690
Each function **call** has its own *stack frame* for its own copy of variables.

```c
int factorial(int n) {
    if (n == 1) {
        return 1;
    } else {
        return n * factorial(n - 1);
    }
}

int main(int argc, char *argv[]) {
    printf("%d", factorial(4));
    return 0;
}
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The Stack with Recursion

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int main(int argc, char *argv[]) {
    printf("%d", factorial(4));
    return 0;
}
```

```
main
argc: 1
argv: 0xffff0
factorial
n: 4
0x0
```

Returns 24
The Stack with Recursion

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}
```
Extra Practice
**strdup** means string duplicate

How can we implement **strdup** using functions we’ve already seen?

```c
1 char *mystrdup(const char *str) {
2     char *heapstr = ____A____;
3     ____B____;
4     ____C____;
5     return heapstr;
6 }
```

[Note] Use library functions:

- `<stdlib.h>`: `malloc`
- `<assert.h>`: `assert`
- `<string.h>`: `strcpy, strlen`
strdup means string duplicate

How can we implement **strdup** using functions we’ve already seen?

```c
1 char *mystrdup(const char *str) {
2     char *heapstr = malloc(strlen(str) + 1);
3     assert(heapstr != NULL);
4     strcpy(heapstr, str);
5     return heapstr;
6 }
```

char arrays differ from other arrays in that valid strings must be null-terminated (i.e., have an extra ending char).
(Note: library strdup doesn’t have an assert—it leaves the assert to the callee)
Where/how should we free memory below so that all memory is freed properly?

```c
1 char *str = strdup("Hello");
2 assert(str != NULL);
3 char *ptr = str + 1;
4 for (int i = 0; i < 5; i++) {
    5 int *num = malloc(sizeof(int));
    6 *num = i;
    7 printf("%s %d\n", ptr, *num);
4 }
9 printf("%s\n", str);
```

**Recommendation:** Don’t worry about putting in frees until after you’re finished with functionality. Memory leaks will rarely crash your CS107 programs.

**Answer in chat:**

“After line N: free(...);”

What if we didn’t free?

```
valgrind --leak-check=full --show-leak-kinds=all ...
```
Goodbye, Free Memory

Where/how should we free memory below so that all memory is freed properly?

```c
char *str = strdup("Hello");
assert(str != NULL);
char *ptr = str + 1;
for (int i = 0; i < 5; i++) {
    int *num = malloc(sizeof(int));
    *num = i;
    printf("%s %d\n", ptr, *num);
    free(num);
}
printf("%s\n", str);
free(str);
```

**Recommendation**: Don’t worry about putting in frees until after you’re finished with functionality.
Memory leaks will rarely crash your CS107 programs.
Write a function that takes in a heap-allocated `str1`, enlarges it, and concatenates `str2` onto it.

```c
char *strcat_extend(char *heap_str, const char *concat_str) {
    (_________________(1)__________________);

    heap_str = realloc(___(2A)__,___(2B)___);

    (_________________(3)__________________);

    strcat(___(4A)__, ___(4B)___);

    return heapstr;
}
```

Example usage:

```c
char *str = strdup("Hello ");
str = strcat_extend(str, "world!");
printf("%s\n", str);
free(str);
```
Write a function that takes in a heap-allocated `str1`, enlarges it, and concatenates `str2` onto it.

```c
char *strcat_extend(char *heap_str, const char *concat_str) {
    int new_length = strlen(heap_str) + strlen(concat_str) + 1;
    heap_str = realloc(heap_str, new_length);
    assert(heap_str != NULL);
    strcat(heap_str, concat_str);
    return heapstr;
}
```

Example usage:
```
char *str = strdup("Hello ");
str = strcat_extend(str, "world!");
printf("%s\n", str);
free(str);
```