CSc 352

Malloc, Free, Stack, Heap

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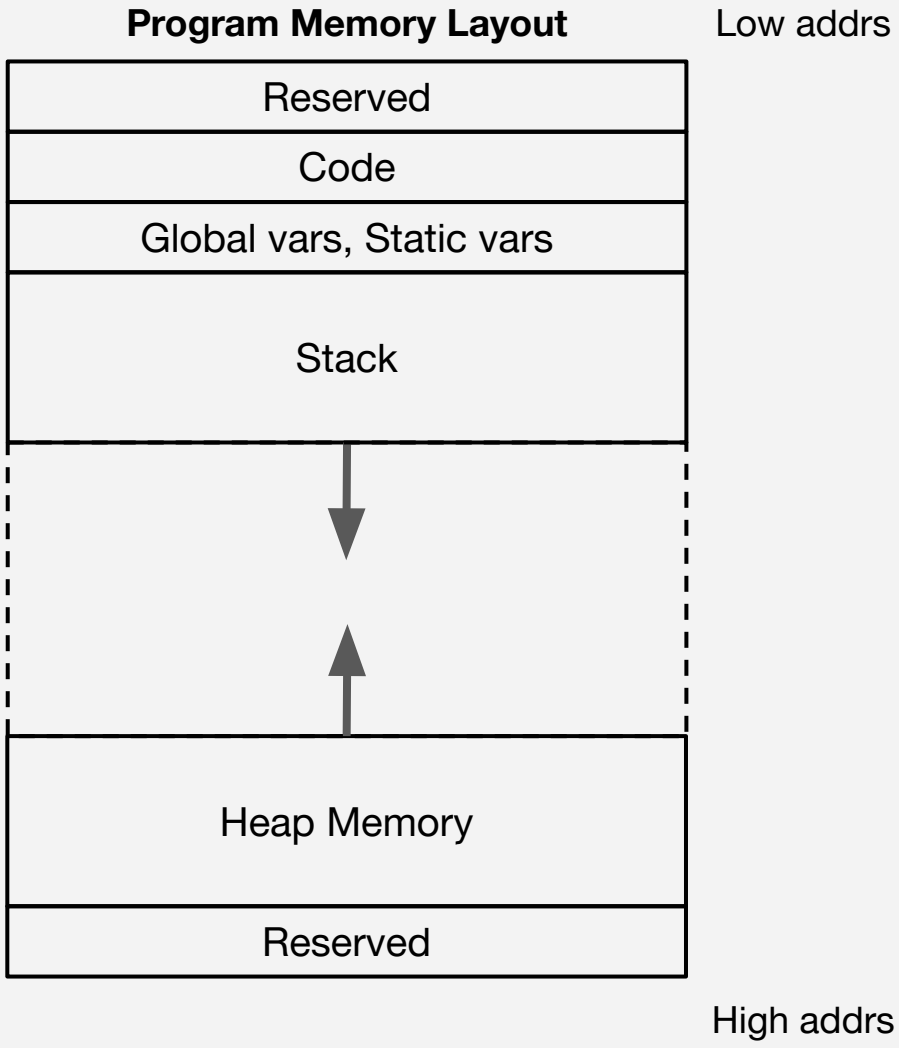
Program Layout

When a program is loaded into memory and run, this is the general memory organization and layout

Exact layout could change depending on the specific OS



What could it print?

```c
#include <stdio.h>

void zeroes() {
  char z[10];
  for (int i = 0; i < 10; i++) {
    z[i] = 'z';
  }
}

void return_char_ptr(char ** r) {
  char z[10] = "abcdefghi";
  *r = z;
}
```

```c
int main() {
  char * y;
  return_char_ptr(&y);
  printf(">%s<\n", y);
  zeroes();
  printf(">%s<\n", y);
  return 0;
}
```

Stack Diagram

```c
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void zeroes() {
  char z[10];
  for (int i = 0; i < 10; i++) {
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int main() {
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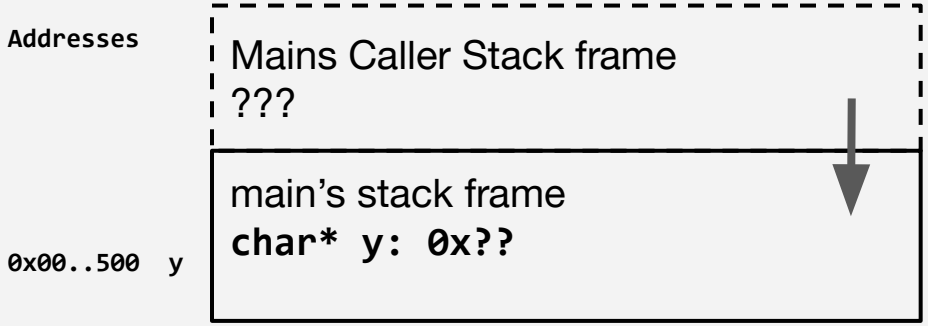
}
```



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  char * y;
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  printf(">%s<\n", y);
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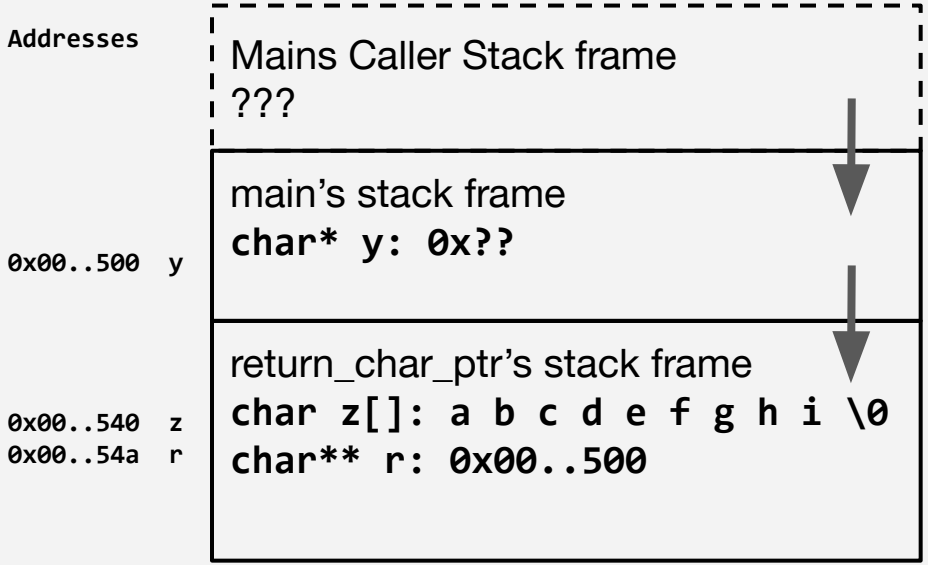
}
```



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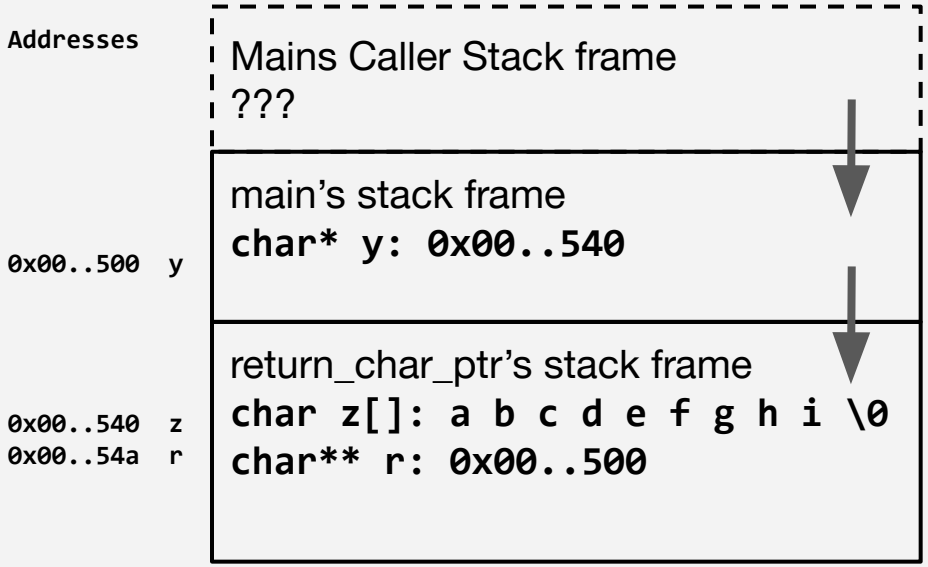

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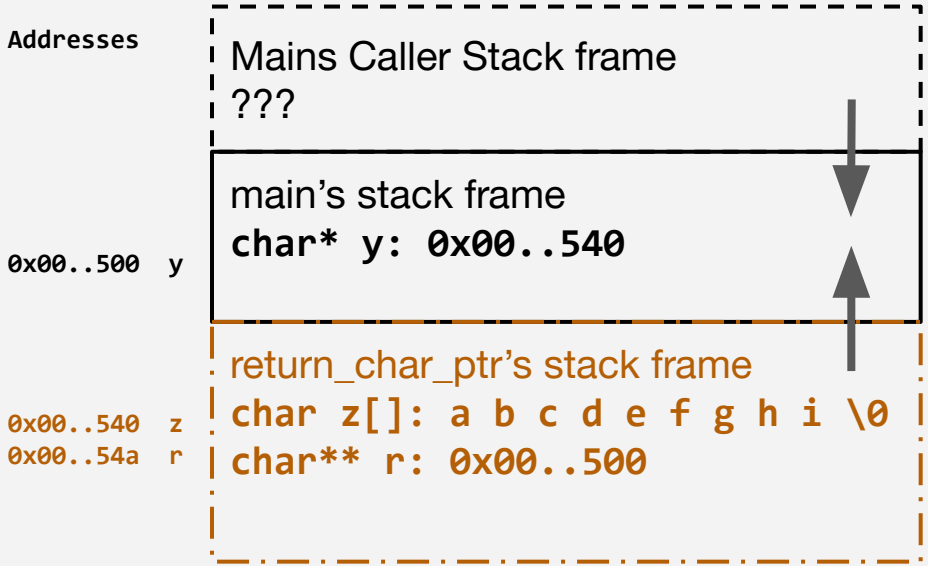

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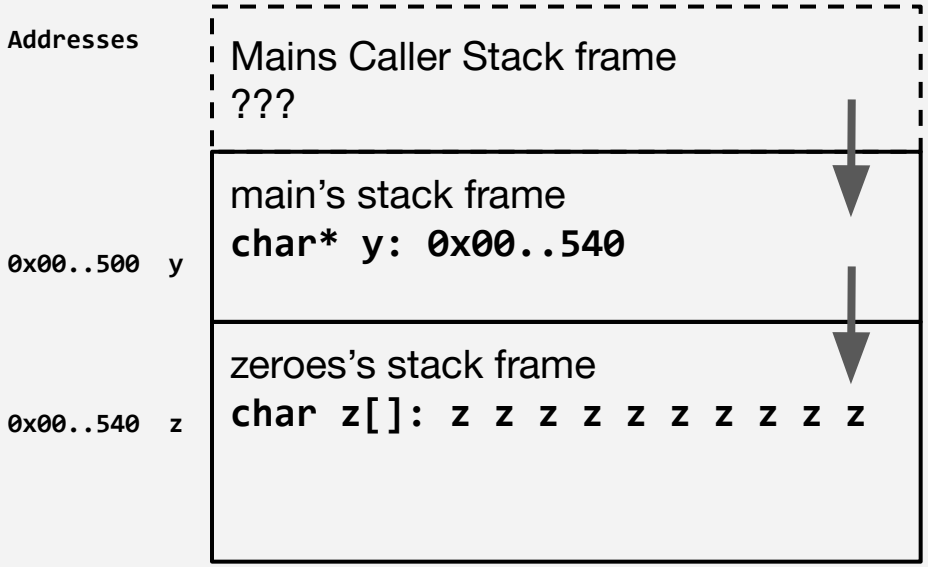
  return 0;
}
```



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int main() {
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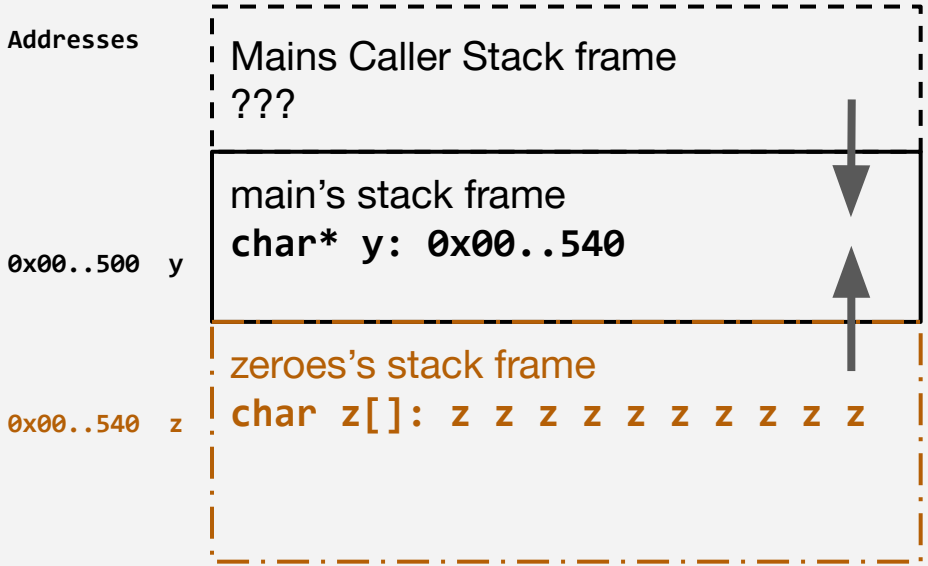
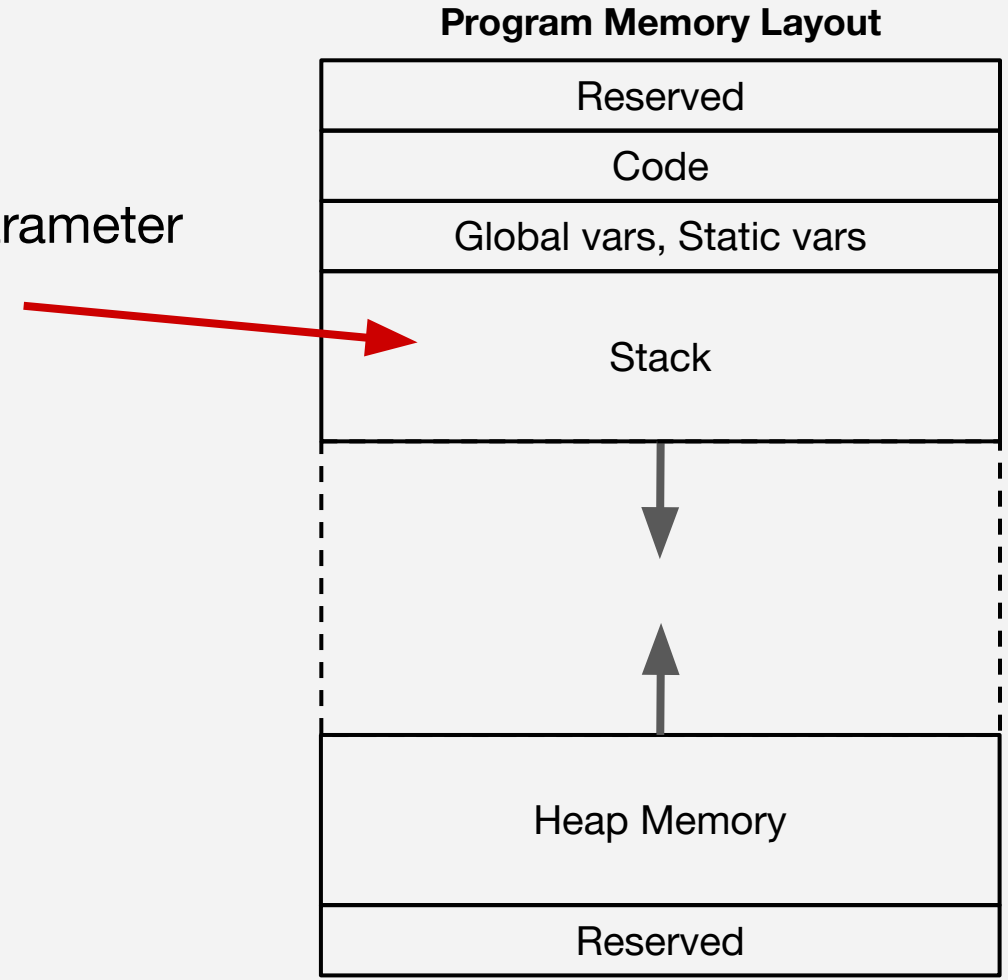
  printf(">%s<\n", y);
  zeroes();
  printf(">%s<\n", y);
  return 0;
}
```



Stack Memory

When we create and use local / parameter vars, allocation happens here

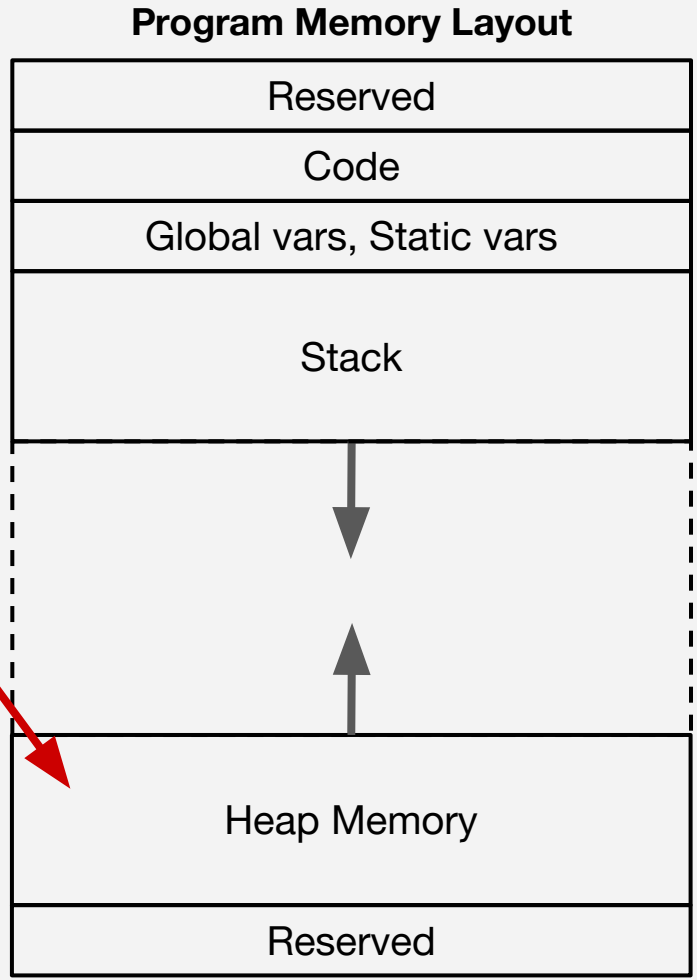


Malloc

The malloc function lets you allocate memory that is not on the stack! Finally!

```
void* malloc(size_t size);
```

Returns a void * (generic pointer) to a chunk of heap memory of **size** bytes, or NULL if malloc fails



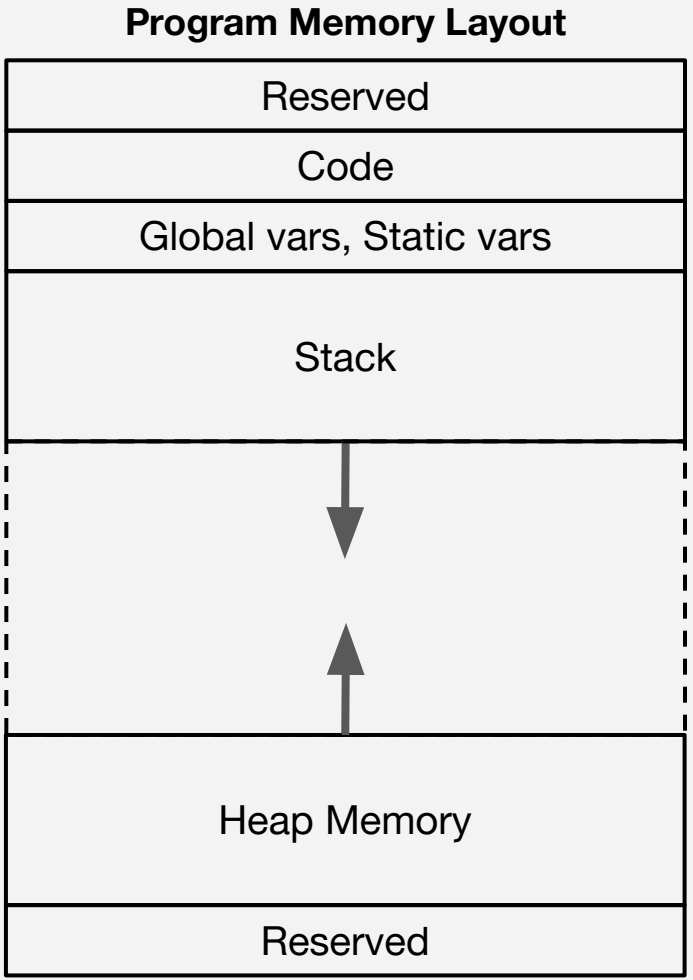
Malloc

Malloc is useful for:

When you have a string / array whose lifetime extends beyond the function who created it's stack frame

Allocating space for data structures that will get passed around within the code

What else?

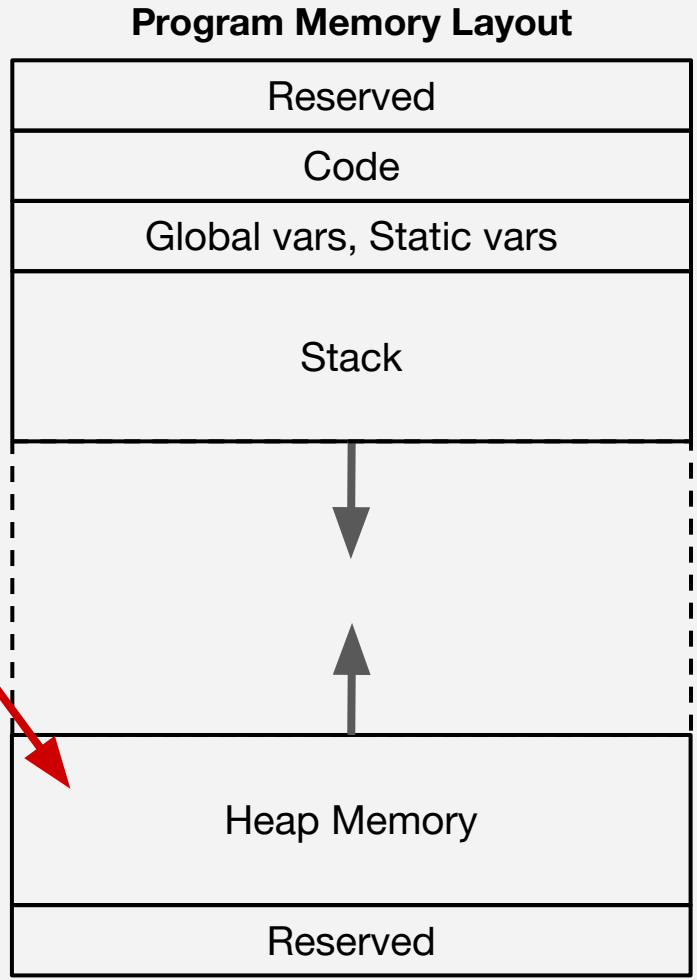


Free

The free function lets you de-allocate (free up) memory that was previously allocated with malloc

```
void free(void* ptr);
```

- Frees the memory.
- *EVERY* time you are finished will malloc'ed memory, you should call free
- If not, could have memory leak



calloc

```
void* calloc(size_t n_items, size_t size);
```

allocates **n_items * size bytes**, initializes the data to zeroes

What will it print?

```c
#include <stdio.h>
#include <stdlib.h>
void zeroes() {
  char * z = malloc(10);
  for (int i = 0; i < 10; i++) {
    z[i] = 'z';
  }
}

void return_char_ptr(char ** r) {
  char * z = malloc(10);
  for (int i = 0; i < 10; i++) {
    z[i] = 'w';
  }
  *r = z;
}
```

```c
int main() {
  char * y;
  return_char_ptr(&y);
  printf(">%s<\n", y);
  zeroes();
  printf(">%s<\n", y);
  return 0;
}
```

What will it print?

```c
#include <stdio.h>
#include <stdlib.h>
void zeroes() {
  char * z = malloc(10);
  for (int i = 0; i < 10; i++) {
    z[i] = 'z';
  }
}

void return_char_ptr(char ** r) {
  char * z = malloc(10);
  for (int i = 0; i < 10; i++) {
    z[i] = 'w';
  }
  *r = z;
}
```

```c
int main() {
  char * y;
  return_char_ptr(&y);
  printf(">%s<\n", y);
  zeroes();
  printf(">%s<\n", y);
  return 0;
}
```

What am I doing wrong?

Recap:

- **`void* malloc(size_t size);`**
  - Allocates **size** bytes and returns the pointer to it, or NULL if failed to alloc
- **`void* calloc(size_t n_items, size_t size);`**
  - Allocates **(n_items* size)** bytes and returns the pointer to it, or NULL if failed to alloc
- **`void free(void * ptr);`**
  - Frees the memory pointer to by **ptr** so that your program can no longer rely on having access to that memory

What will this do?

```c
#include <stdio.h>
#include <stdlib.h>

void zeroes() {
  char * z = malloc(100000);
}

int main() {
  for (int i = 0; i < 10000000; i+=1) {
    zeroes();
  }
  return 0;
}
```

What will this do?

```c
#include <stdio.h>
#include <stdlib.h>

void zeroes() {
  char * z = malloc(100000);
}

int main() {
  for (int i = 0; i < 10000000; i+=1) {
    zeroes();
  }
  return 0;
}
```

Let's inspect with **top**

Implement the function

- Write a function named **dynamic_strcat**
- Takes two params, **`char*`**s, pointing to two C strings
- Function allocates memory that fits both strings, concats them, and returns the pointer

Implement the function

- Write a function named **dynamic_split**
- Takes one params, **`char*`** pointing to a C string
- returns a **`char**`**, a pointer to a sequence of pointers to the words from the parameter split on a space.

Activity

```c
#define LARGE 250

char* get_longest_line() {
  char* longest = NULL;
  char* line_buffer = malloc(LARGE);
  while(fgets(line_buffer, LARGE, stdin) != NULL) {
    int length = strlen(line_buffer);
    if (longest == NULL || length > strlen(longest)) {
      longest = malloc(length+1);
      longest[length] = '\0';
      strncpy(longest, line_buffer, length);
    }
  }
  return longest;
}

int main() {
  char* longest_line = get_longest_line();
  printf("The longest line from standard input is:\n");
  printf("%s\n", longest_line);
  free(longest_line);
  return 0;
}
```

What does this code accomplish?

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#define LARGE 250

char* get_longest_line() {
  char* longest = NULL;
  char* line_buffer = malloc(LARGE);
  while(fgets(line_buffer, LARGE, stdin) != NULL) {
    int length = strlen(line_buffer);
    if (longest == NULL || length > strlen(longest)) {
      longest = malloc(length+1);
      longest[length] = '\0';
      strncpy(longest, line_buffer, length);
    }
  }
  return longest;
}

int main() {
  char* longest_line = get_longest_line();
  printf("The longest line from standard input is:\n");
  printf("%s\n", longest_line);
  free(longest_line);
  return 0;
}
```

What is WRONG with how this is written?

```c
#define LARGE 250

char* get_longest_line() {
  char* longest = NULL;
  char* line_buffer = malloc(LARGE);
  while(fgets(line_buffer, LARGE, stdin) != NULL) {
    int length = strlen(line_buffer);
    if (longest == NULL || length > strlen(longest)) {
      longest = malloc(length+1);
      longest[length] = '\0';
      strncpy(longest, line_buffer, length);
    }
  }
  return longest;
}

int main() {
  char* longest_line = get_longest_line();
  printf("The longest line from standard input is:\n");
  printf("%s\n", longest_line);
  free(longest_line);
  return 0;
}
```

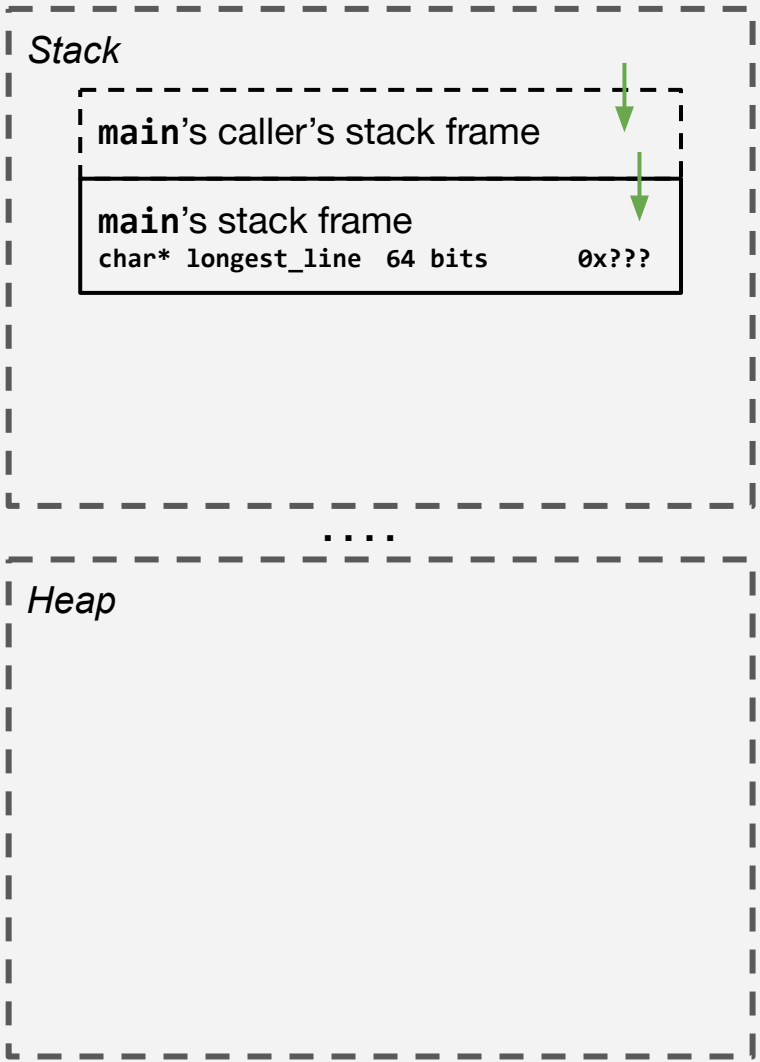
Input:

```
abcdefghijk
abcdefghijklmnop
abcdefghijklmnopqrs
abcdefghijklmnopqrstuv
```

```c
#define LARGE 250

char* get_longest_line() {
  char* longest = NULL;
  char* line_buffer = malloc(LARGE);
  while(fgets(line_buffer, LARGE, stdin) != NULL) {
    int length = strlen(line_buffer);
    if (longest == NULL || length > strlen(longest)) {
      longest = malloc(length+1);
      longest[length] = '\0';
      strncpy(longest, line_buffer, length);
    }
  }
  return longest;
}

int main() {
  char* longest_line = get_longest_line();
  printf("The longest line from standard input is:\n");
  printf("%s\n", longest_line);
  free(longest_line);
  return 0;
}
```



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    }
  }
  return longest;
}

int main() {
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  free(longest_line);
  return 0;
}
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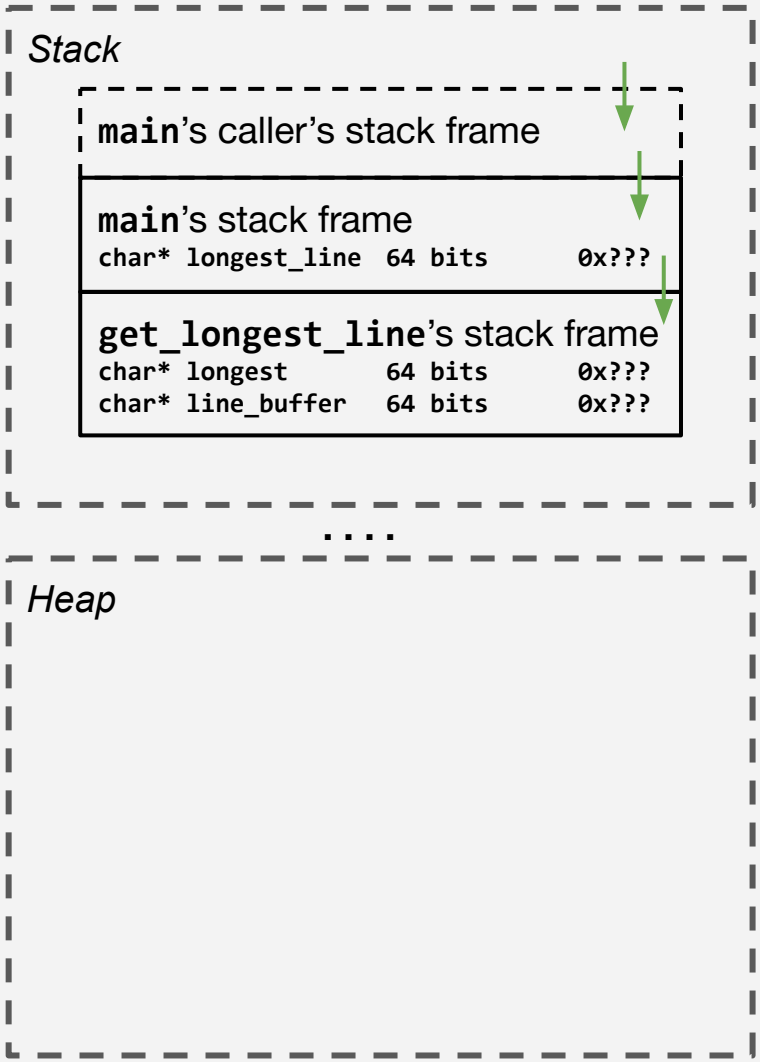

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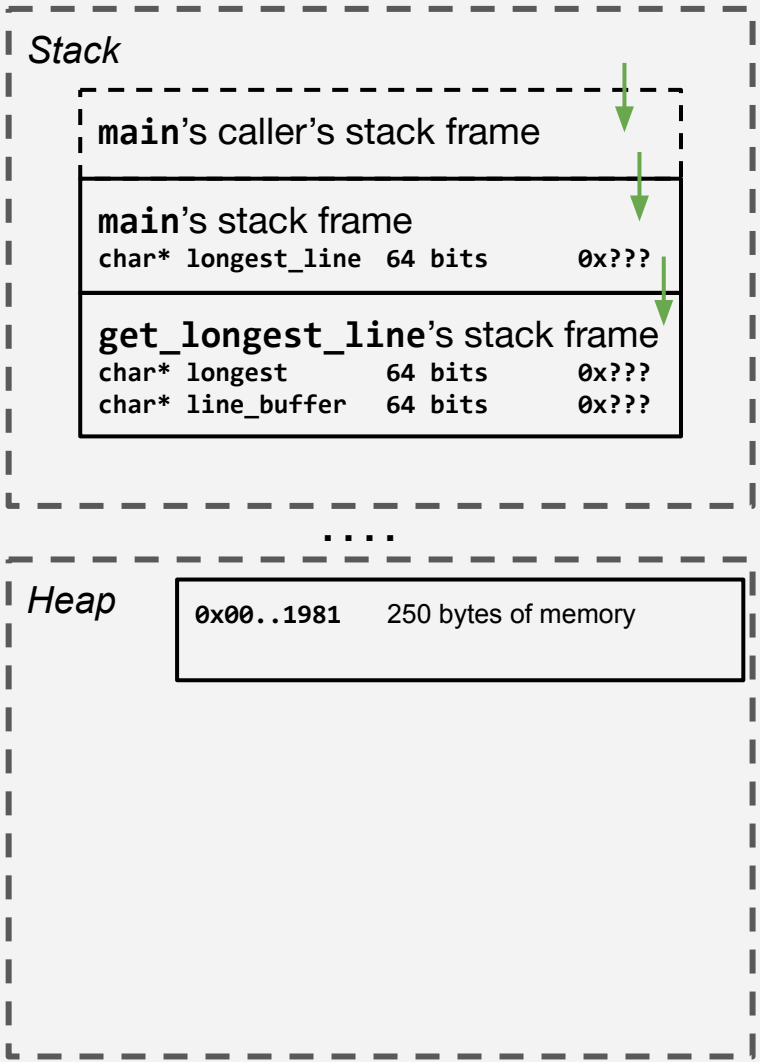
    int length = strlen(line_buffer);
    if (longest == NULL || length > strlen(longest)) {
      longest = malloc(length+1);
      longest[length] = '\0';
      strncpy(longest, line_buffer, length);
    }
  }
  return longest;
}

int main() {
  char* longest_line = get_longest_line();
  printf("The longest line from standard input is:\n");
  printf("%s\n", longest_line);
  free(longest_line);
  return 0;
}
```



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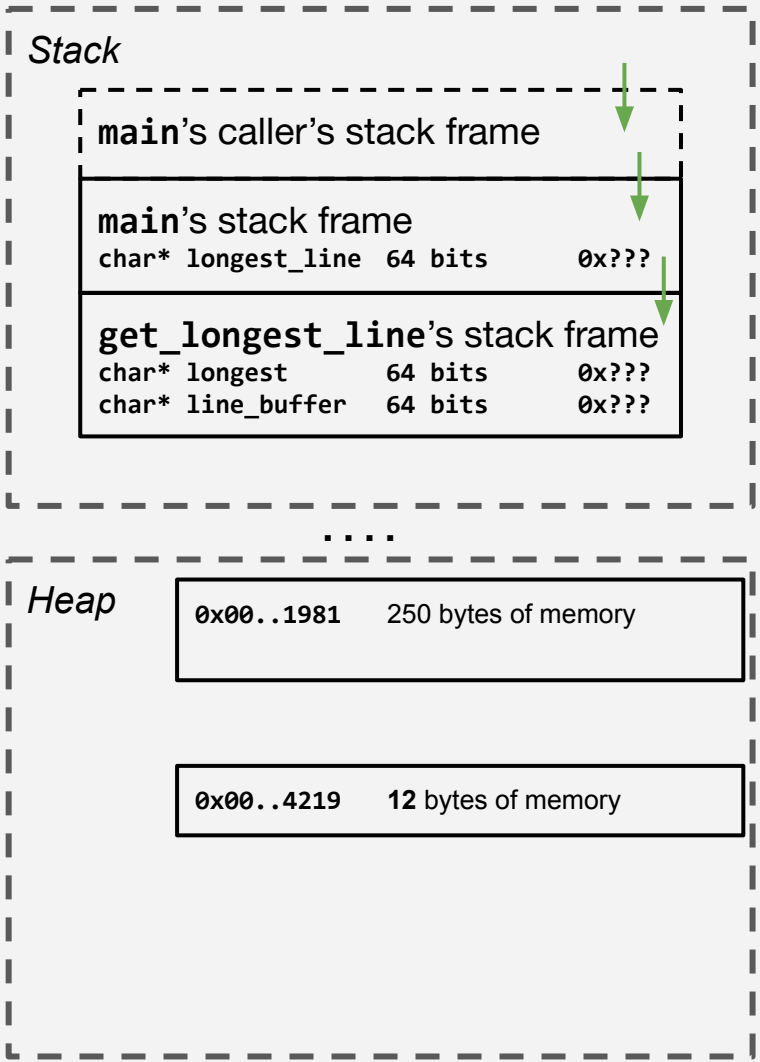

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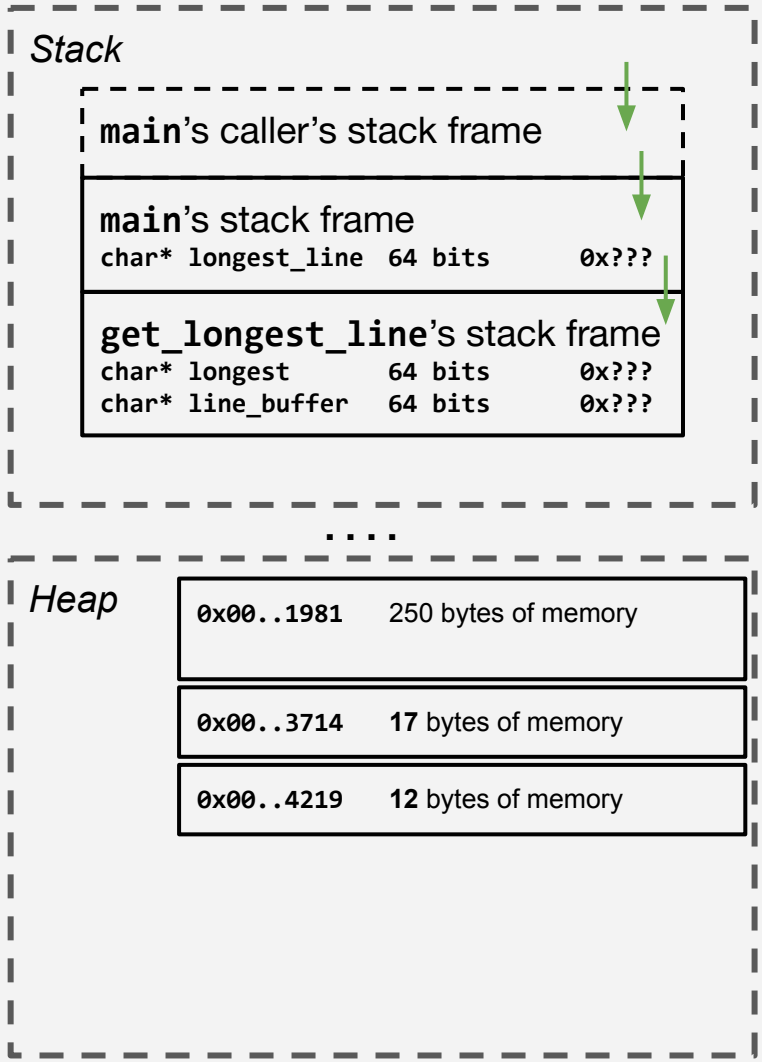

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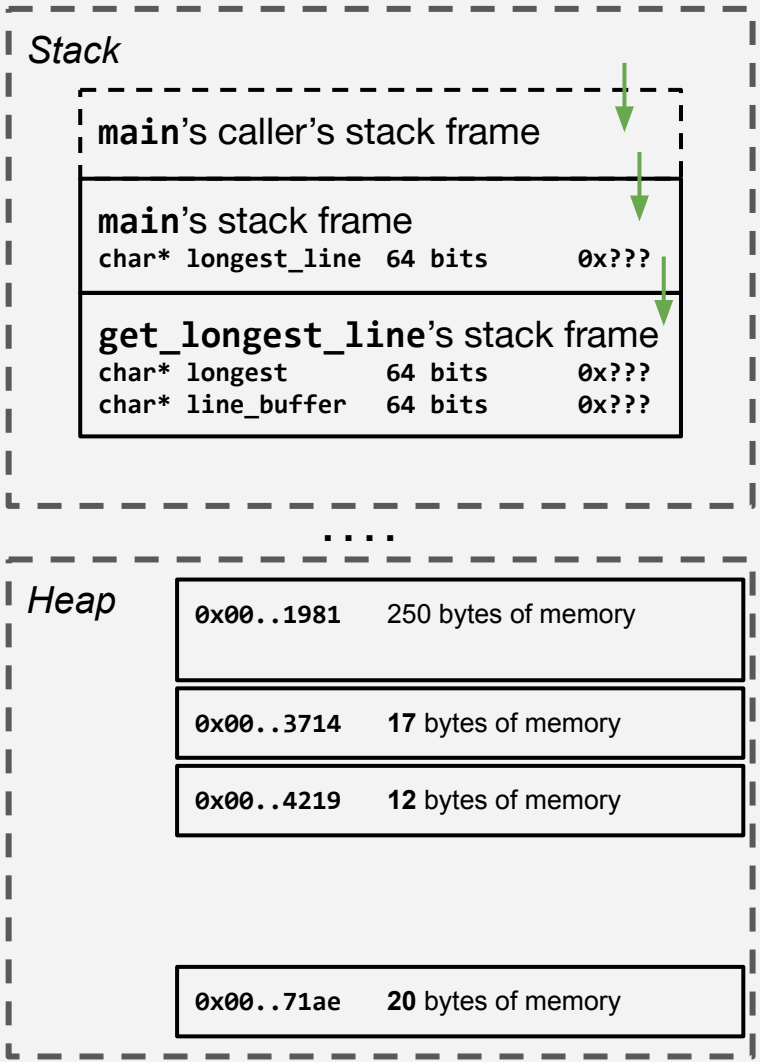

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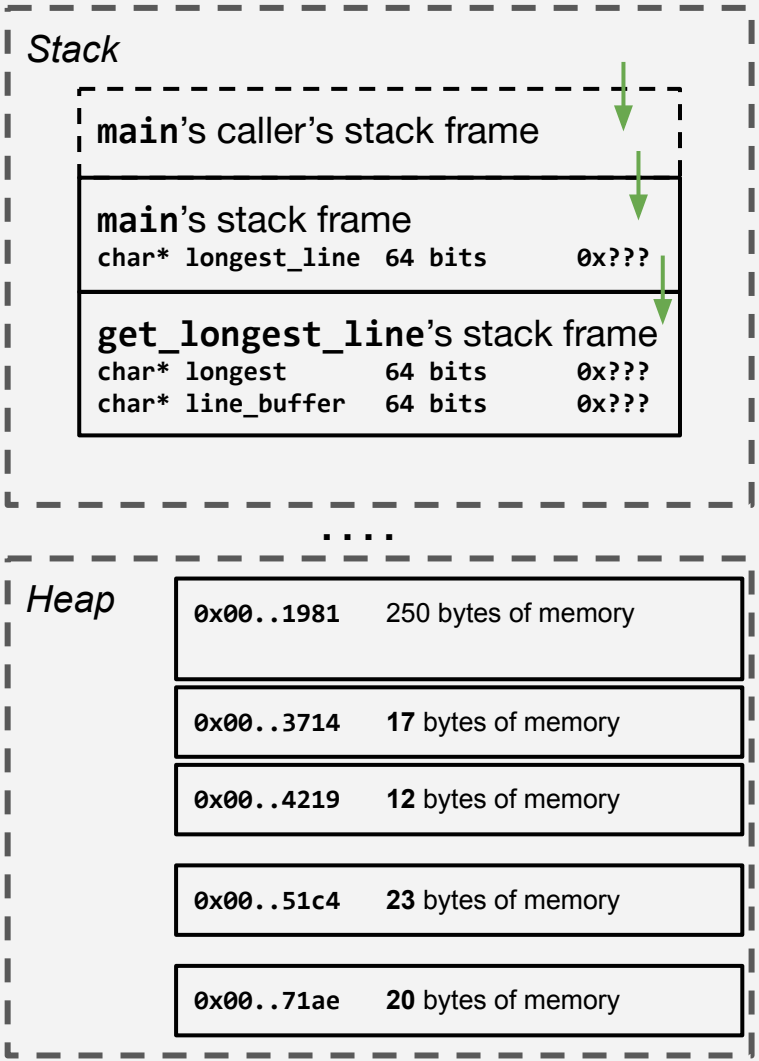

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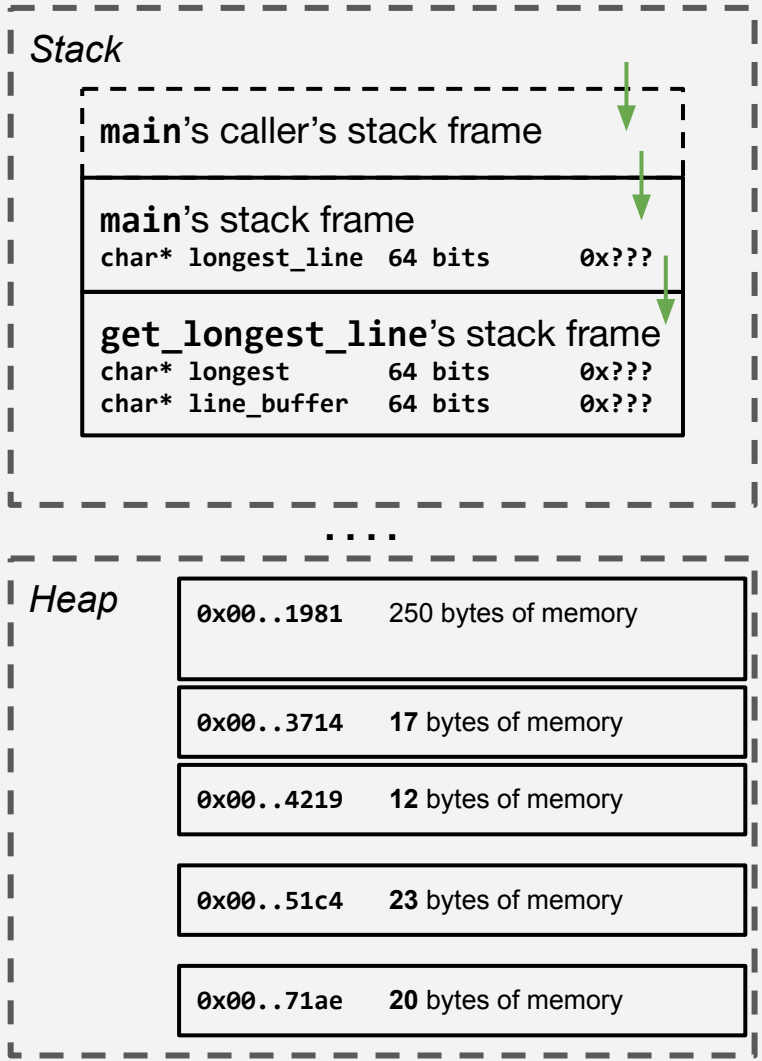

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  free(longest_line);
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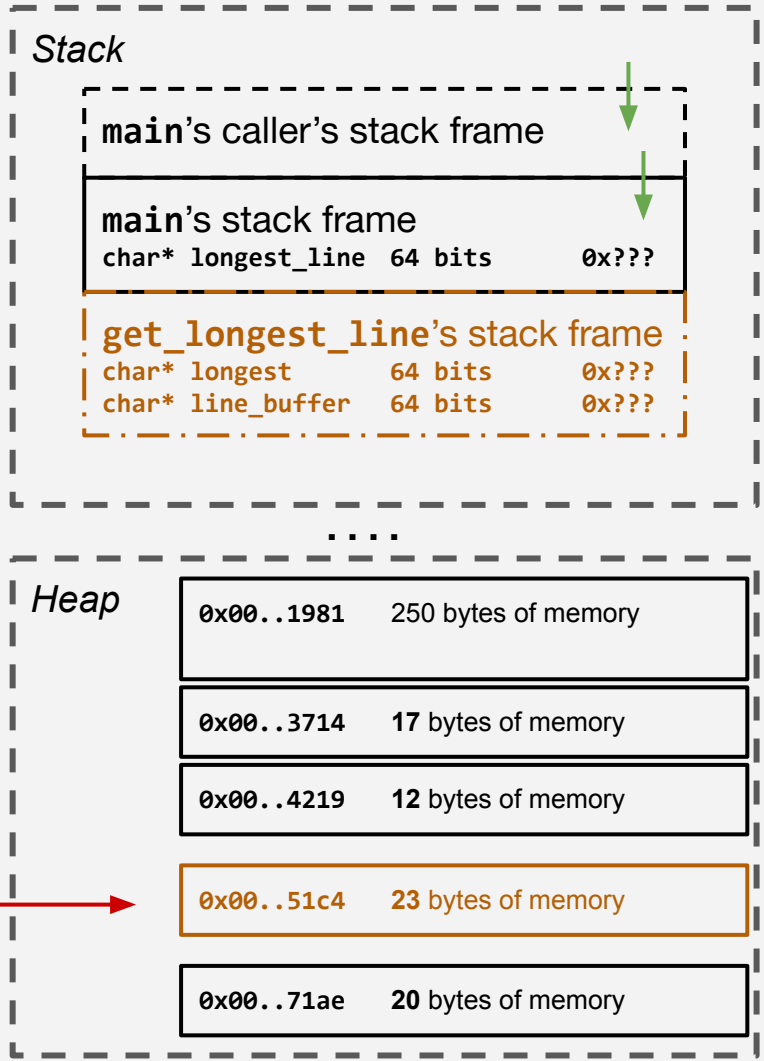
}
```

Memory freed



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      longest[length] = '\0';
      strncpy(longest, line_buffer, length);
    }
  }
  return longest;
}

int main() {
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  printf("The longest line from standard input is:\n");
  printf("%s\n", longest_line);
  free(longest_line);
  return 0;
}
```

What about these though?