Memory Allocation

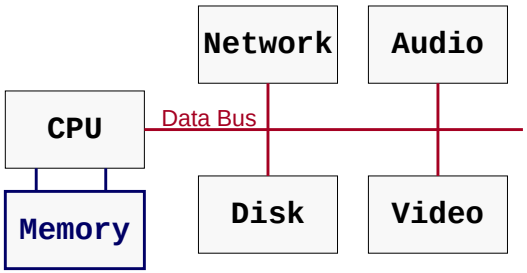
CS 217

Memory Allocation

- Good programmers make efficient use of memory
- Understanding memory allocation is important
  - Create data structures of arbitrary size
  - Avoid “memory leaks”
  - Run-time performance

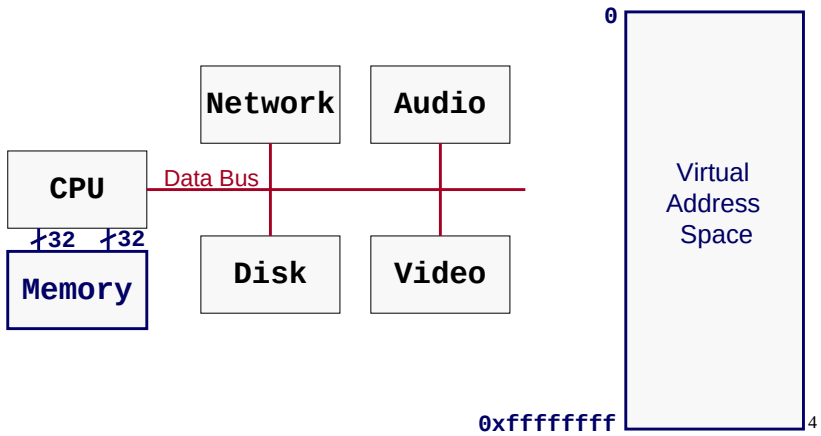
Memory

- What is memory?
  - Storage for variables, data, code, etc.



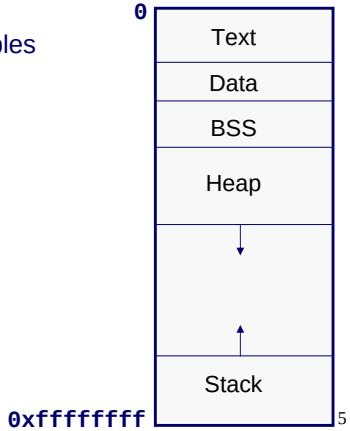
Memory

- What is memory?
  - Storage for variables, data, code, etc.
  - Unix provides virtual memory



Memory Layout

- How is memory organized?
  - Text = code, constant data
  - Data = initialized global and static variables
  - BSS = (Block Started by Symbol) uninitialized (zero) global & static variables
  - Stack = local variables
  - Heap = dynamic memory



Memory Layout

```
char string = "hello"
int iSize;

char *f(void)
{
    char *p;
    iSize = 8;
    p = malloc(iSize);
    return p;
}
```

data

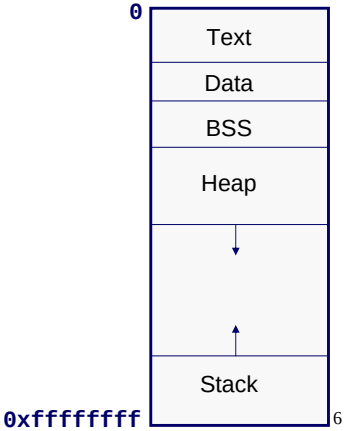
text (or "read-only data")

bss

stack

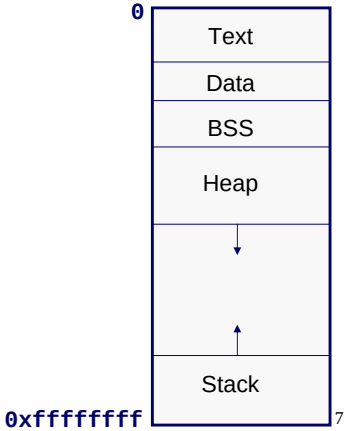
text

heap



Memory Allocation

- How is memory allocated?
  - Global and static variables = program startup
  - Local variables = function call
  - Dynamic memory = malloc()



Memory Allocation

```
int iSize;

char *f(void)
{
    char *p;
    iSize = 8;
    p = malloc(iSize);
    return p;
}
```

← allocated in BSS, set to zero at startup

← allocated on stack at start of function **f**

← 8 bytes allocated in heap by **malloc**

Memory Deallocation

- How is memory deallocated?
  - Global and static variables = program finish
  - Local variables = function return
  - Dynamic memory = free()
- All memory is deallocated at program termination
  - It is good style to free allocated memory anyway

Memory Deallocation

```
int iSize;                          ← available until program termination

char *f(void)
{
    char *p;                        ← deallocated by return from function f
    iSize = 8;
    p = malloc(iSize);              ← deallocate by calling free(p)
    return p;
}
```


Dynamic Memory

```
#include <stdlib.h>
void *malloc(size_t size);
void free(void *ptr);
```

size_t is a typedef for an appropriate-sized unsigned int, e.g., typedef unsigned size_t

```
char *p1 = malloc(3);
char *p2 = malloc(1);
char *p3 = malloc(4);
free(p2);
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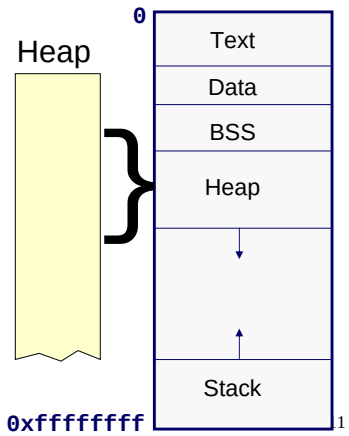

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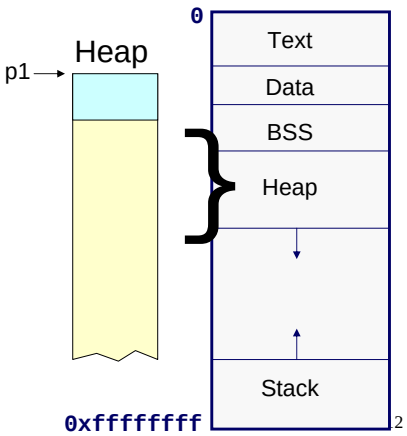

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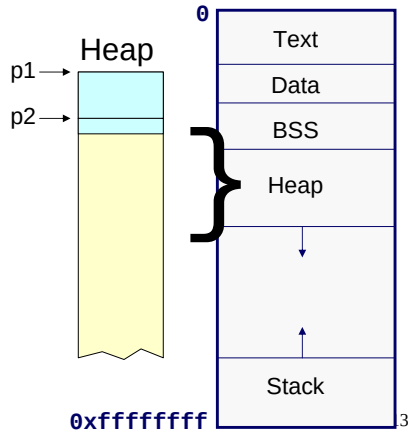

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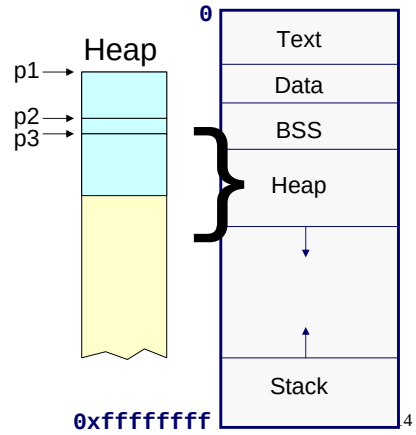

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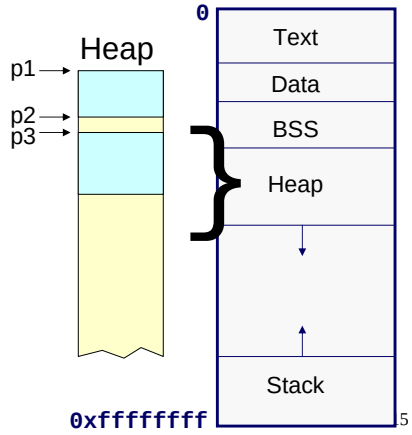

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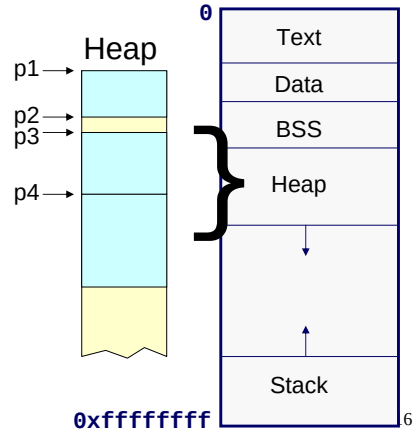

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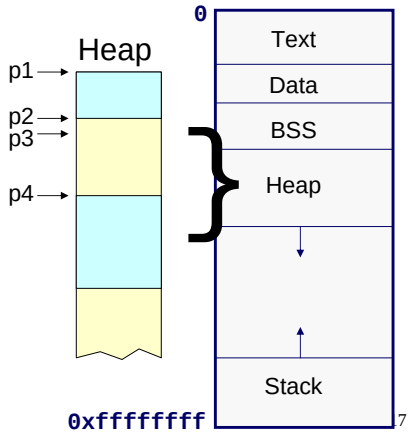

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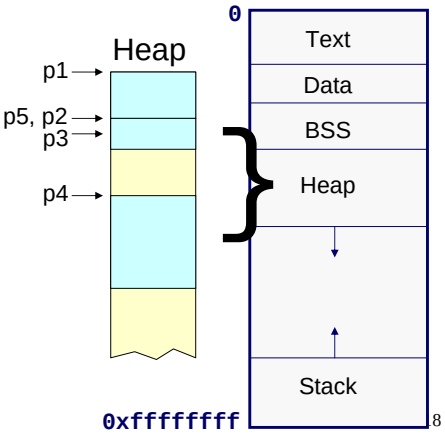

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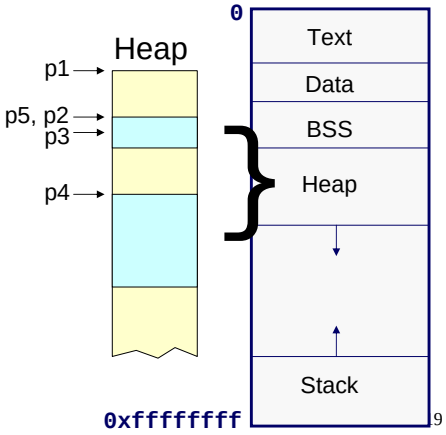

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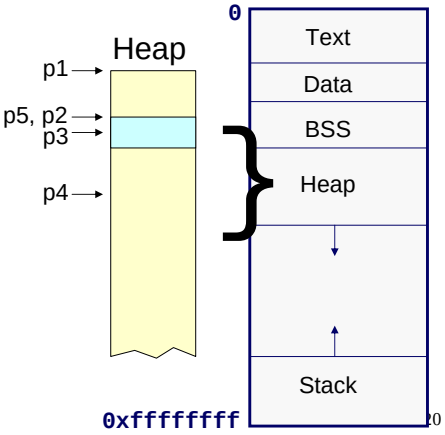
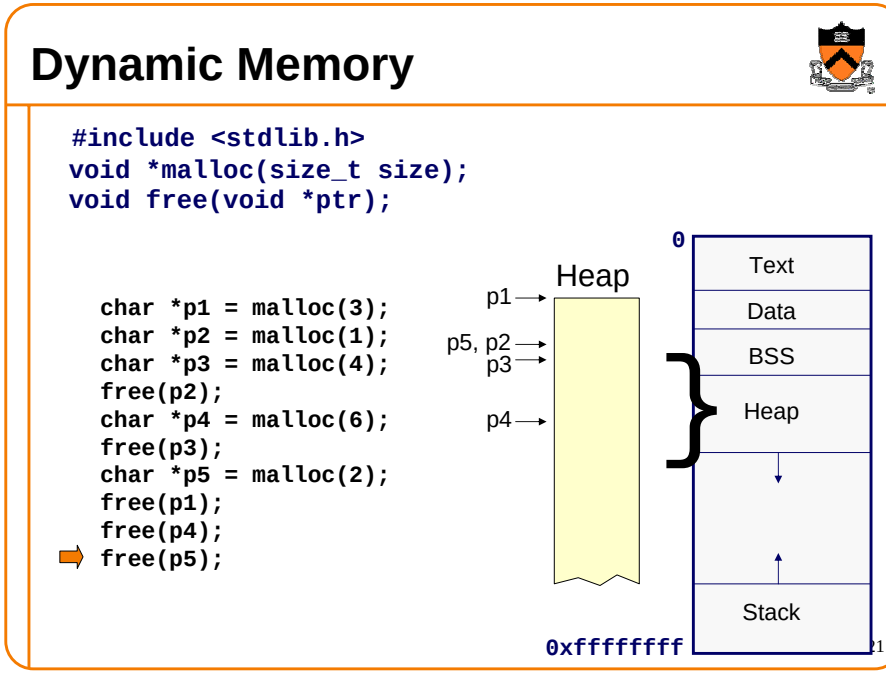


Dynamic Memory



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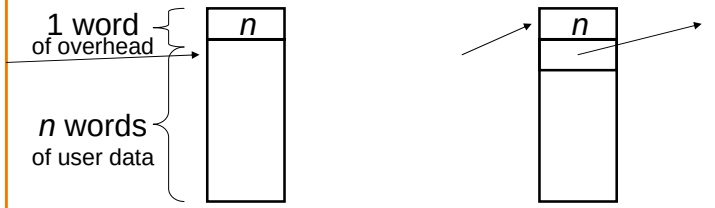
Memory allocator ADT

- Malloc & free are the operations of an ADT
  - How do they work inside?
- First answer: it's an ADT, you're not supposed to ask!
- Second answer:

malloc(s)
n = ⌈s / sizeof(int)⌉

free(p)
put p into linked list of free objects



Dangling pointers

- Dangling pointers point to data that's not there anymore
- Avoid dangling pointers!
- Example:

Example Code I

```
...

void ReadStrings(Array_T strings, FILE *fp)
{
  char buffer[MAX_STRING_LENGTH];
  while (fgets(buffer, MAX_STRING_LENGTH, fp)) {
    Array_insert(strings, buffer);
  }
}

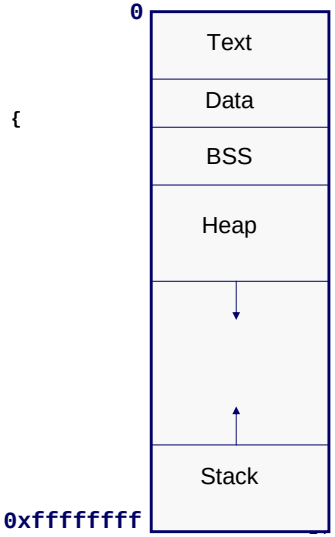
...

int main()
{
  Array_T strings = Array_new();

  ReadStrings(strings, stdin);
  SortStrings(strings, strcmp);
  WriteStrings(strings, stdout);

  Array_free(strings);

  return 0;
}
```



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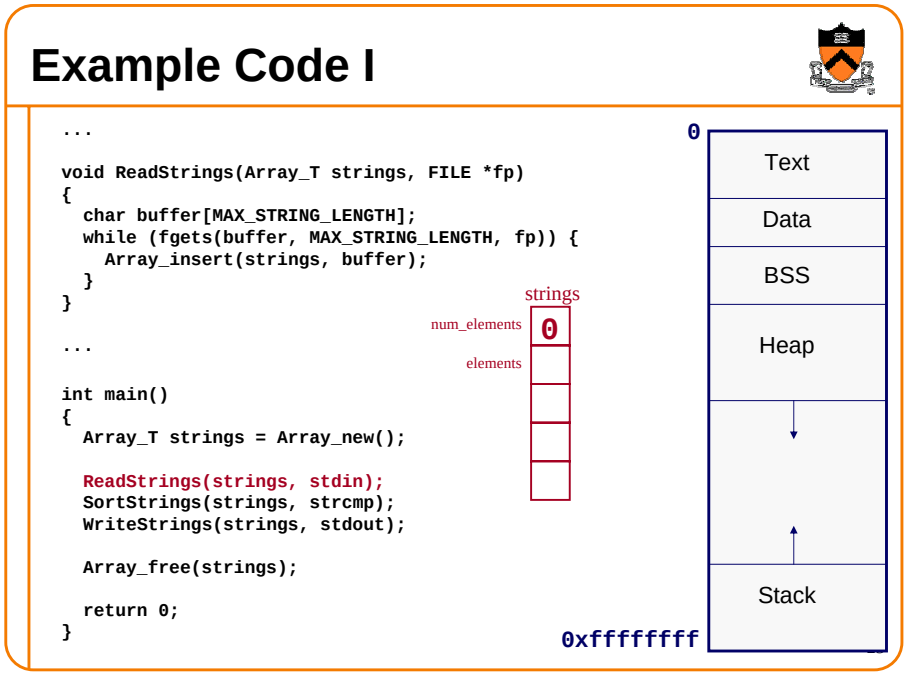

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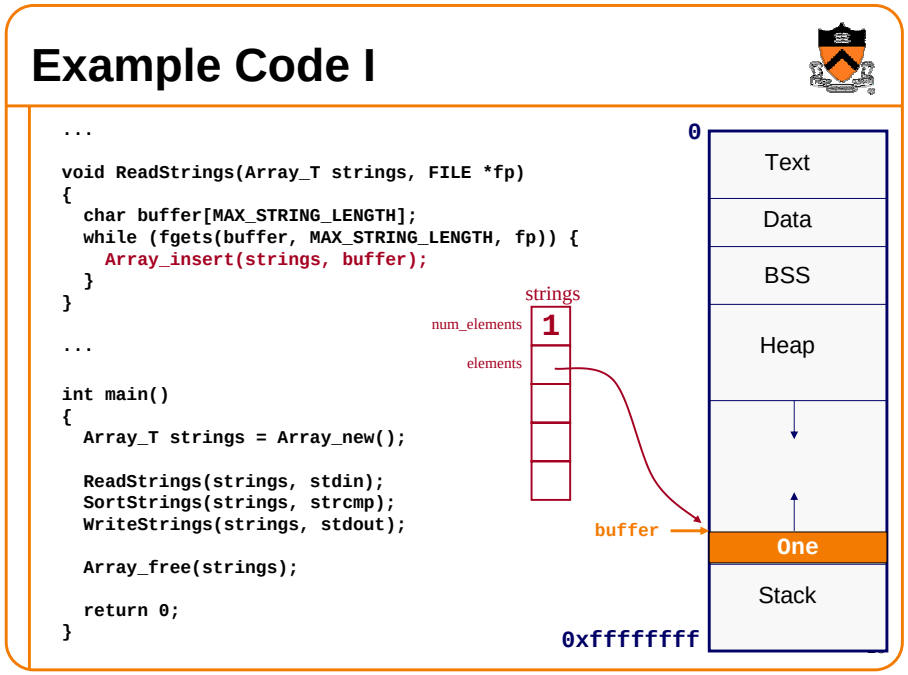

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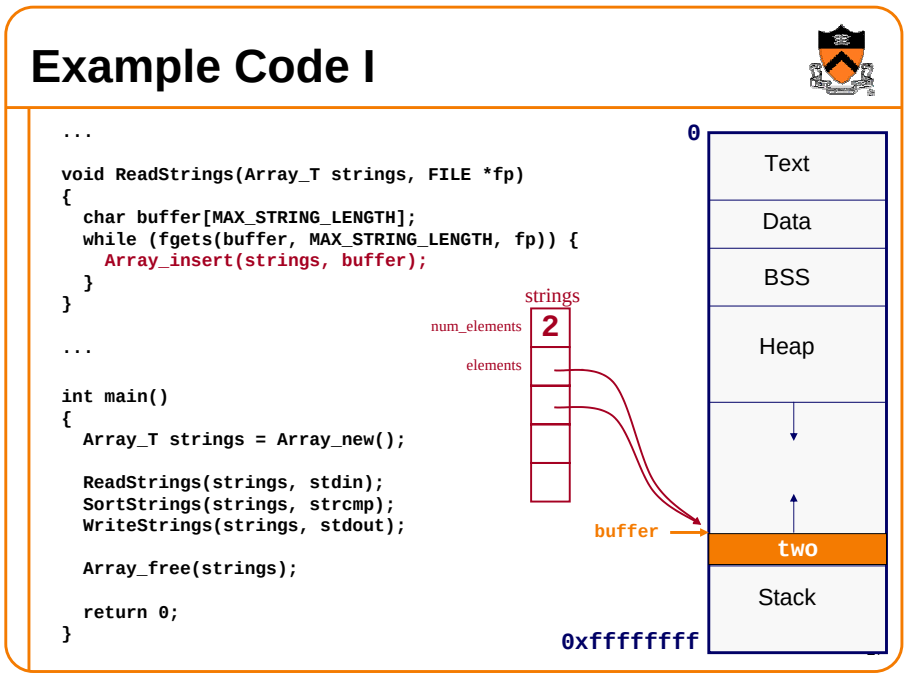

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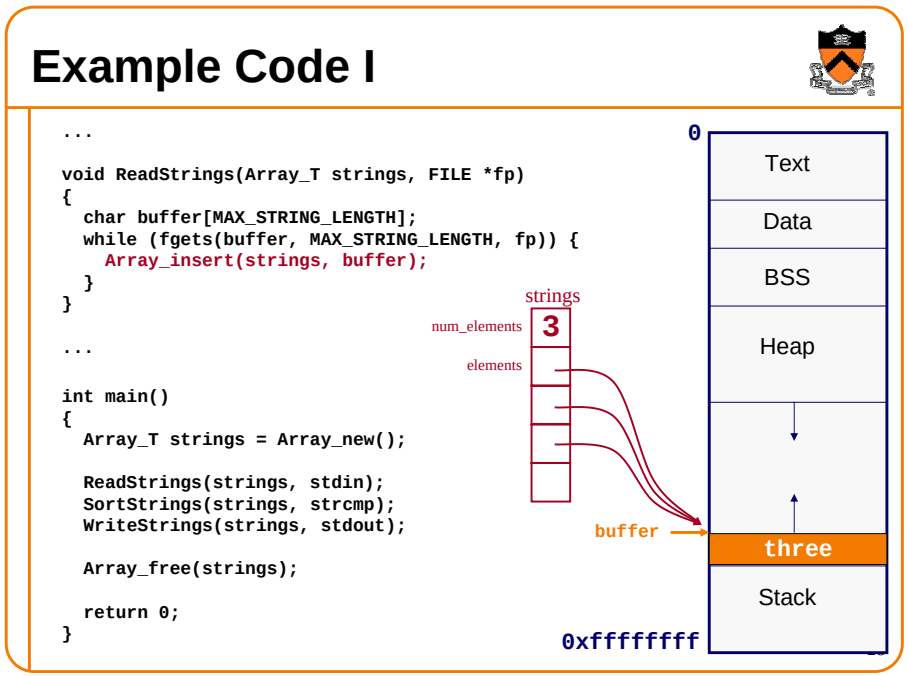

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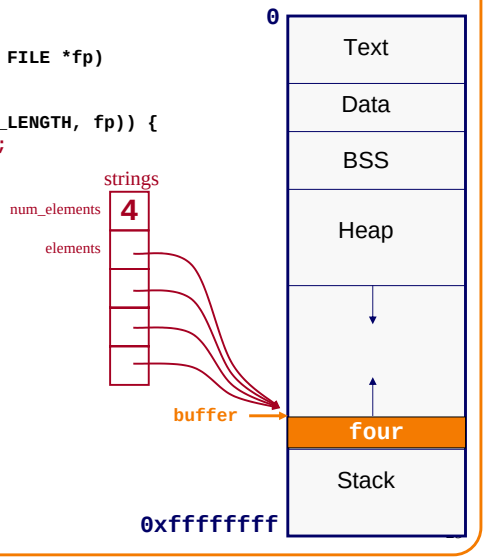

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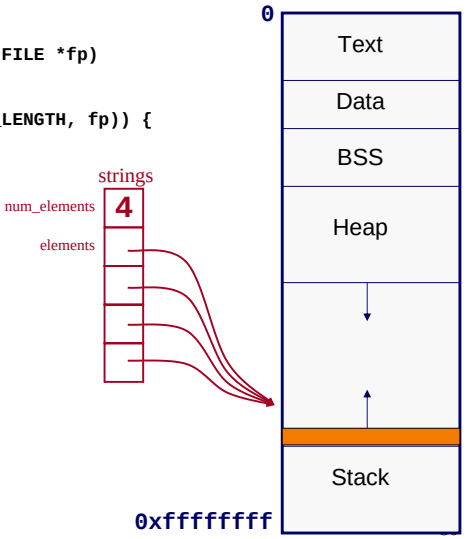

Example Code II

```
...

void ReadStrings(Array_T strings, FILE *fp)
{
  char buffer[MAX_STRING_LENGTH];
  while (fgets(buffer, MAX_STRING_LENGTH, fp)) {
    char *string = malloc(strlen(buffer+1));
    strcpy(string, buffer);
    Array_insert(strings, string);
  }
}

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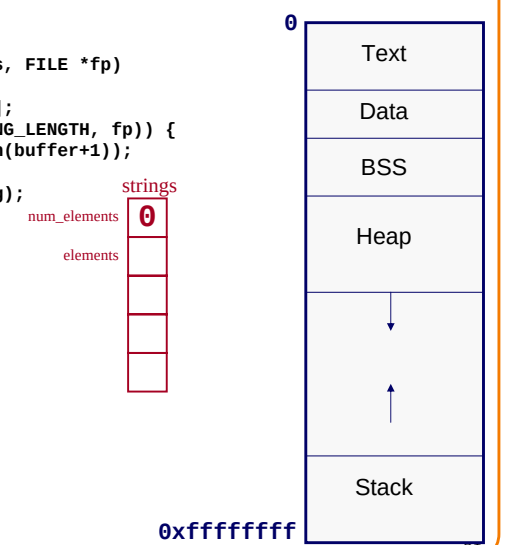

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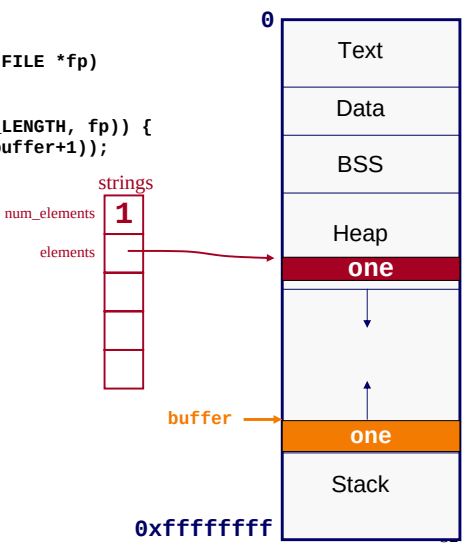

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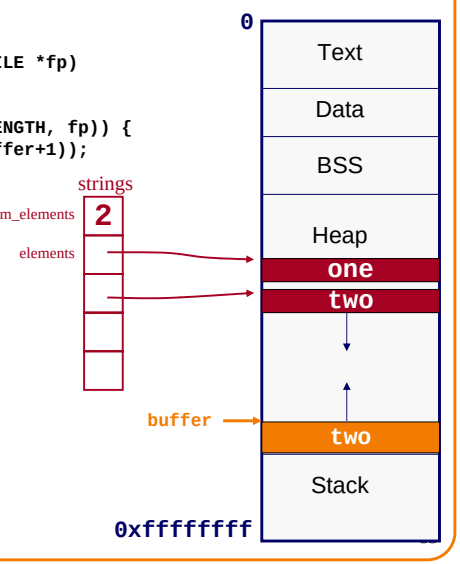

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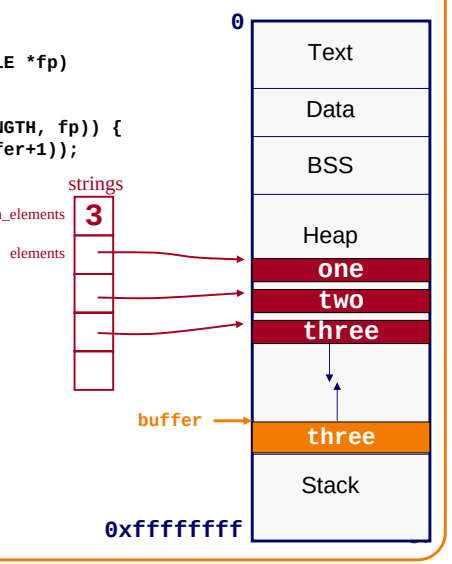

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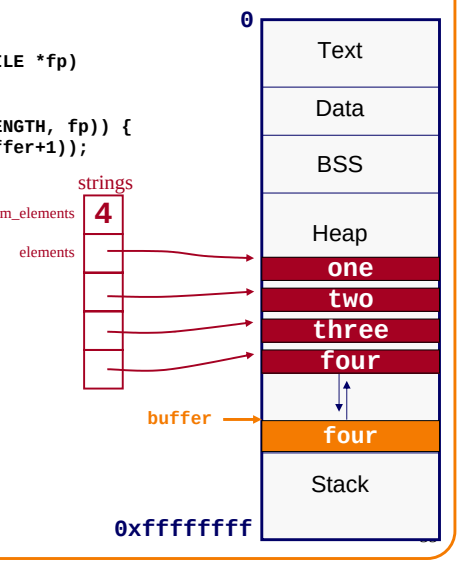

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    strcpy(string, buffer);
    Array_insert(strings, string);
  }
}

int main()
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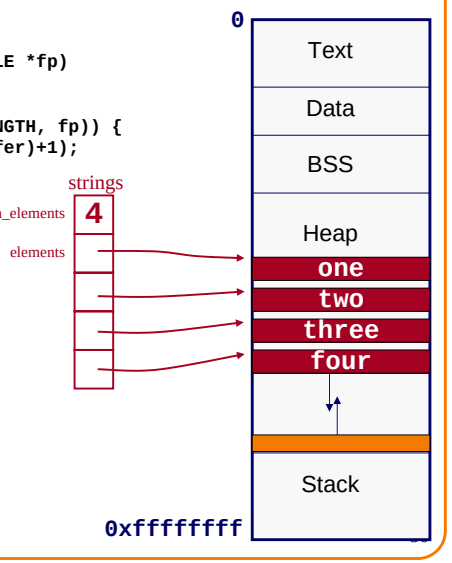
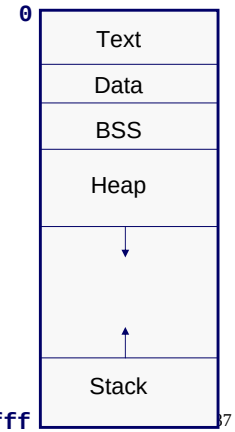


Static Local Variables

- **`static`** keyword in declaration of local variable means:
  - Available (if within scope) throughout entire program execution
  - Variable is allocated from Data or BSS, not stack
  - Acts like global variable with limited scope

```
int iSize;

char *f(void)
{
    static int first = 1;
    if (first) {
      iSize = GetSize();
      first = 0;
    }
    ...
}
```



Memory Initialization

- Local variables have undefined values

```
int count;
```

- Memory allocated by malloc has undefined values

```
char *p = malloc(8);
```

- If you need a variable to start with a particular value, use an explicit initializer

```
int count = 0;
p[0] = '\0';
```

- Global and static variables are initialized to 0 by default

```
static int count = 0;
```

is the same as

```
static int count;
```

It is bad style to depend on this

Summary

- Three types of memory
  - Global and static variables = BSS
  - Local variables = stack
  - Dynamic memory = heap
- Three types of allocation/deallocation strategies
  - Global and static variables (BSS) = program startup/termination
  - Local variables (stack) = function entry/return
  - Dynamic memory (heap) = malloc()/free()
- Take the time to understand the differences!