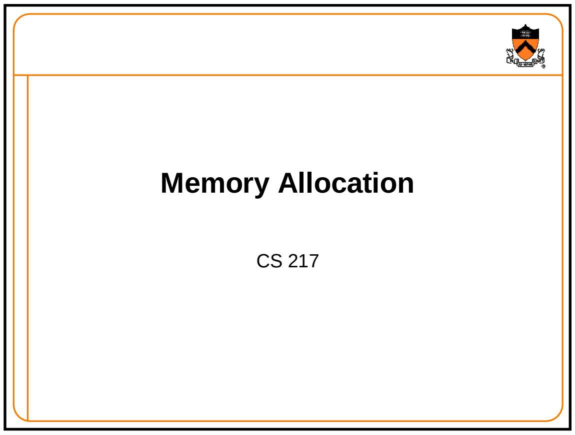
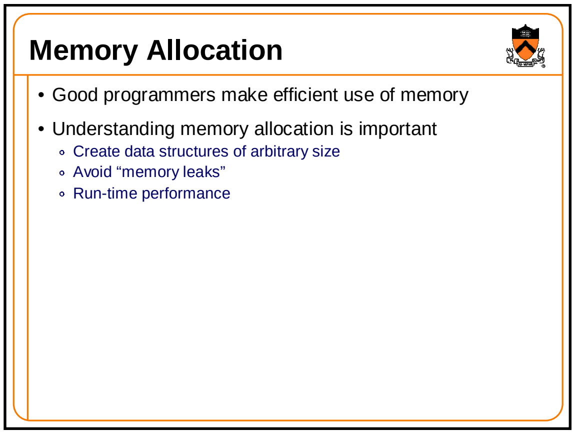


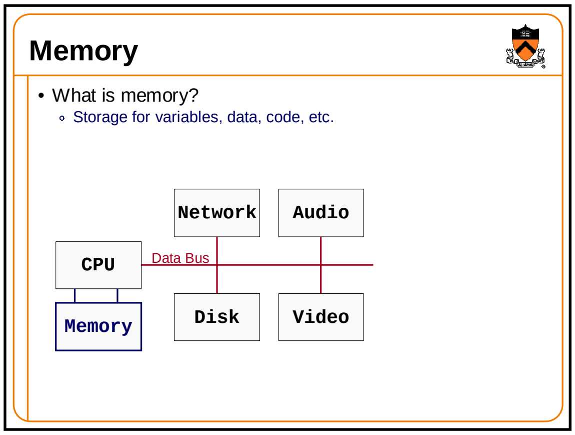
Memory Allocation

CS 217



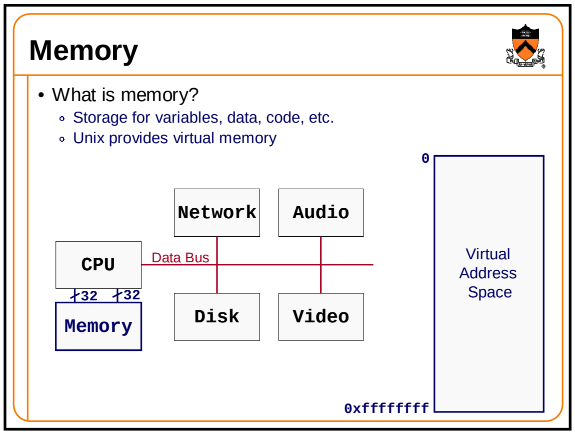
Memory Allocation

- 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

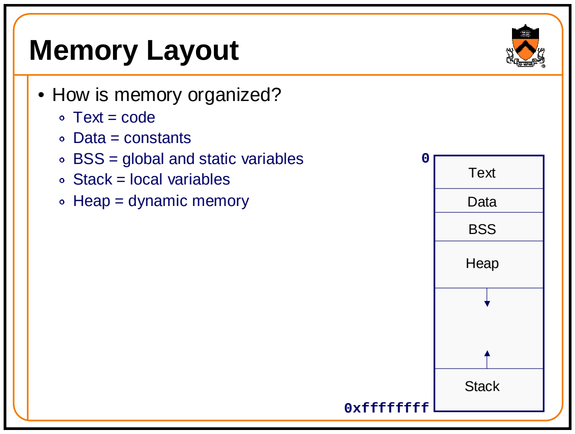
- What is memory?
  - Storage for variables, data, code, etc.



Memory

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

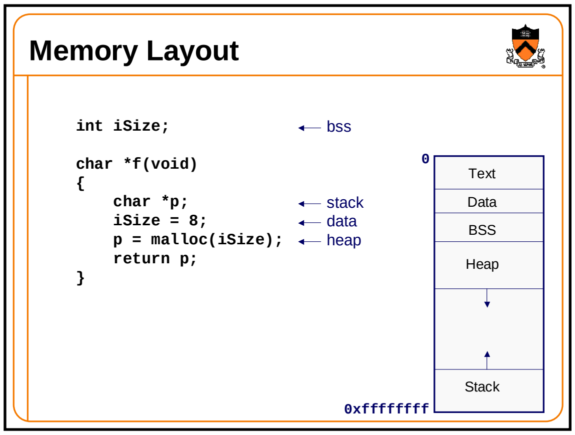
Network
Audio
CPU
Data Bus
32
32
Memory
Disk
Video
0
Virtual Address Space
0xffffffff



Memory Layout

- How is memory organized?
  - Text = code
  - Data = constants
  - BSS = global and static variables
  - Stack = local variables
  - Heap = dynamic memory

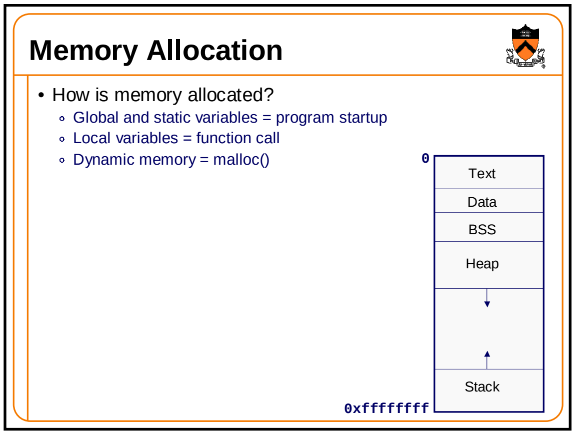
0
Text
Data
BSS
Heap
Stack
0xffffffff



Memory Layout

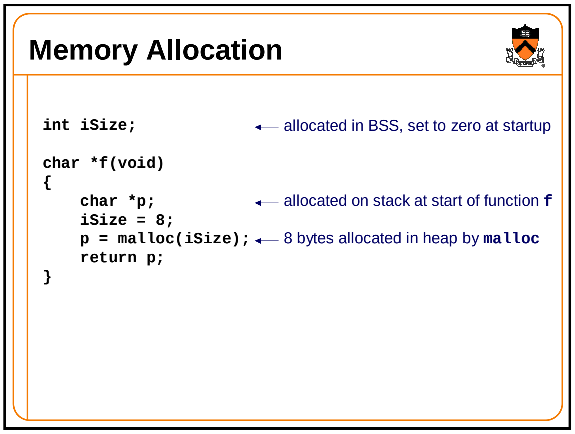
```
int iSize;                ← bss

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

0
Text
Data
BSS
Heap
Stack
0xffffffff



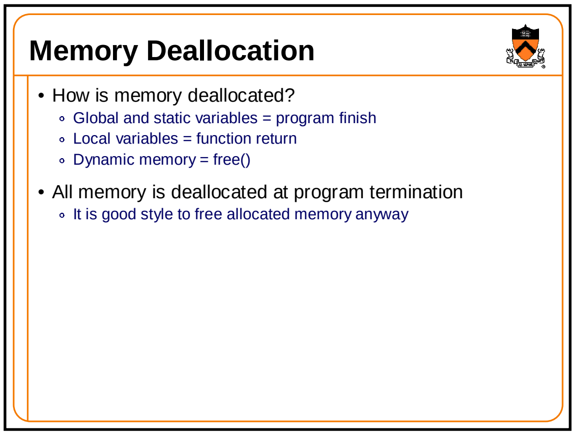
Memory Allocation

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



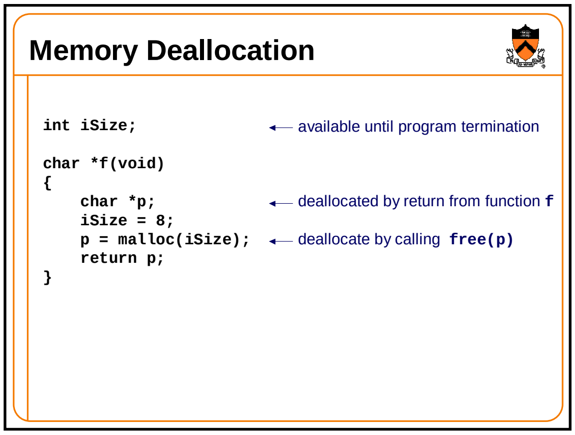
Memory Allocation

```
int iSize;                ← allocated in BSS, set to zero at startup

char *f(void)
{
    char *p;              ← allocated on stack at start of function f
    iSize = 8;
    p = malloc(iSize);    ← 8 bytes allocated in heap by malloc
    return p;
}
```



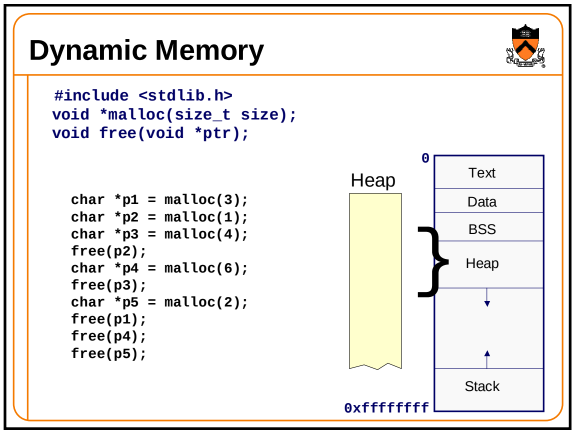
Memory Deallocation

- 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

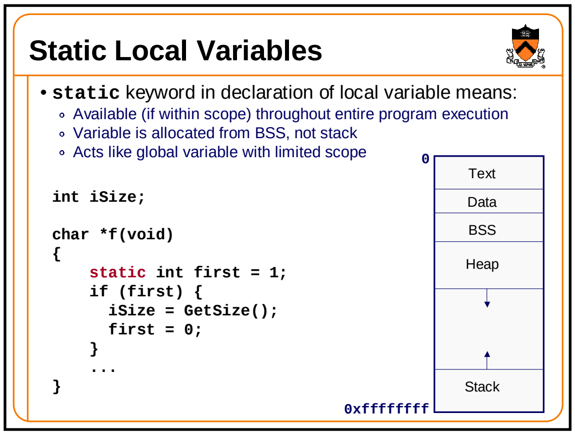
```
int iSize;                    ← available until program termination

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);
```

```
char *p1 = malloc(3);
char *p2 = malloc(1);
char *p3 = malloc(4);
free(p2);
char *p4 = malloc(6);
free(p3);
char *p5 = malloc(2);
free(p1);
free(p4);
free(p5);
```



Static Local Variables

- `static` keyword in declaration of local variable means:
  - Available (if within scope) throughout entire program execution
  - Variable is allocated from 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;
```

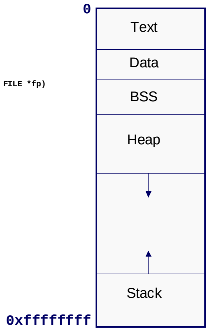
is the same as

```
static int count;
```

It is bad style to depend on this

Example Program

```
#include <stdio.h>
#include <string.h>


#define MAX_STRINGS 128
#define MAX_STRING_LENGTH 256


void ReadStrings(char **strings, int *nstrings, int maxstrings, FILE *fp)
{
  char string[MAX_STRING_LENGTH];

  *nstrings = 0;
  while (fgets(string, MAX_STRING_LENGTH, fp)) {
    strings[(*nstrings)++] = strdup(string);
    if (*nstrings >= maxstrings) break;
  }
}

...

int main()
{
  char *strings[MAX_STRINGS];
  int nstrings;

  ReadStrings(strings, &nstrings, MAX_STRINGS, stdin);
  SortStrings(strings, nstrings);
  WriteStrings(strings, nstrings, stdout);

  return 0;
}
```



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!