CIS 190: C/C++ Programming

Lecture 3

Memory Management in C

Any Questions?

Outline

- (from last class) Testing
- Memory allocation
- Memory errors
- Errors
- Debugging
- Homeworks

Testing

- unit testing
  - literal tests to make sure code works as intended
  - e.g., **`TwoPlusTwoEqualFour(...)`** for an **`Addition()`** function

- ***edge case*** testing (or corner case, etc.)
  - ensure that code performs correctly with all (or at least many) possible input values
  - e.g., prevent program from accepting invalid input

Simple Testing Example

```
/* get month from user in integer form */
printf("Please enter month: ");
scanf("%d", &month);
```

Simple Testing Example

```
/* get month from user in integer form */
printf("Please enter month: ");
scanf("%d", &month);
while (month < JAN_INT || month > DEC_INT)
{



  scanf("%d", &month);
}
```

Simple Testing Example

```
/* get month from user in integer form */
printf("Please enter month: ");
scanf("%d", &month);
while (month < JAN_INT || month > DEC_INT)
{
  printf("\n%d is an invalid month", month);
  printf("please enter between %d and %d:",
         JAN_INT, DEC_INT);
  scanf("%d", &month);
}
```

```
/* print string up to number given
   by length (or full string,
   whichever is reached first) */
void PrintToLength(char str[],
                   int  length)
{
  int i;
  for (i = 0; i < length; i++)
  {
    printf("%c", str[i]);
  }
}
```

Common Edge Cases

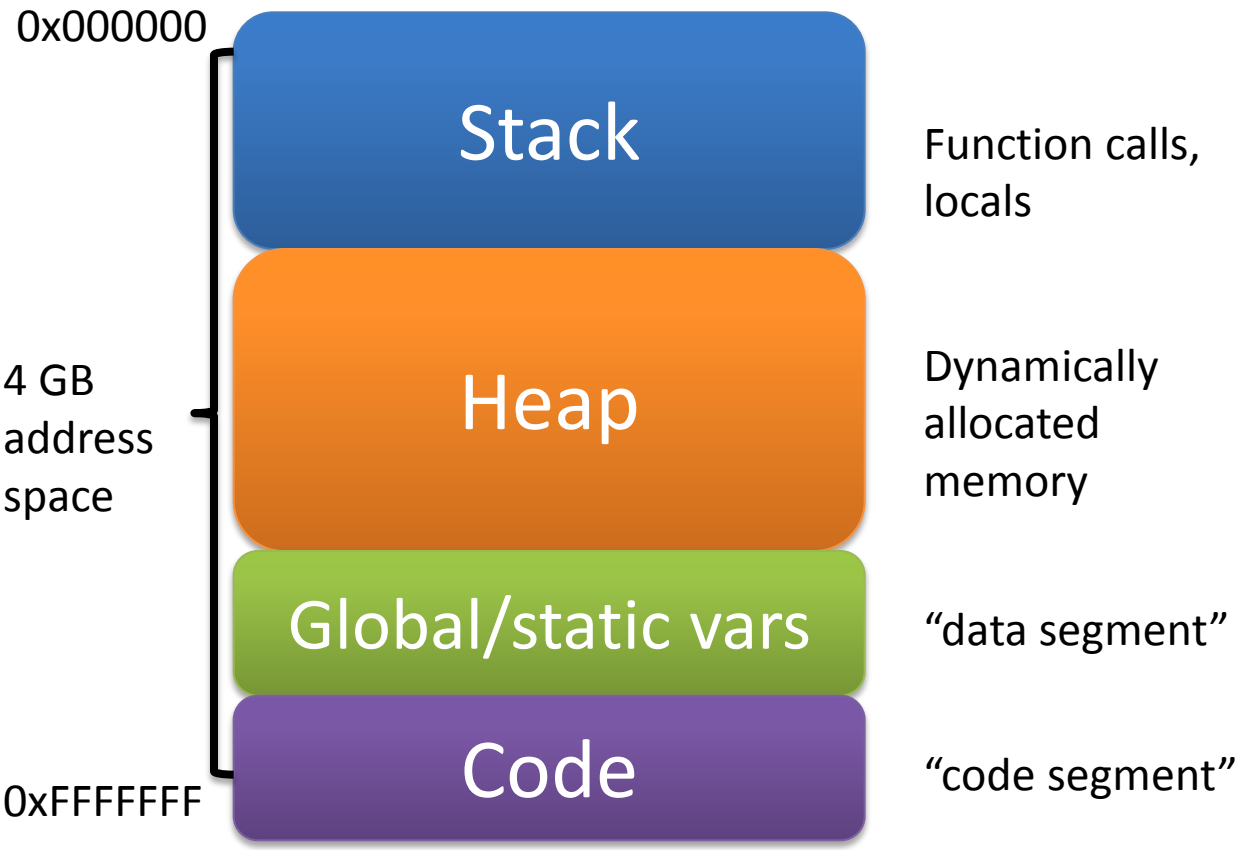
- C-style string
  - empty string
  - pointer to NULL
  - without the \0 terminator
- Integer
  - zero
  - negative/positive
  - below/above the min/max

Outline

- (from last class) Testing
- Memory allocation
- Memory errors
- Errors
- Debugging
- Homeworks

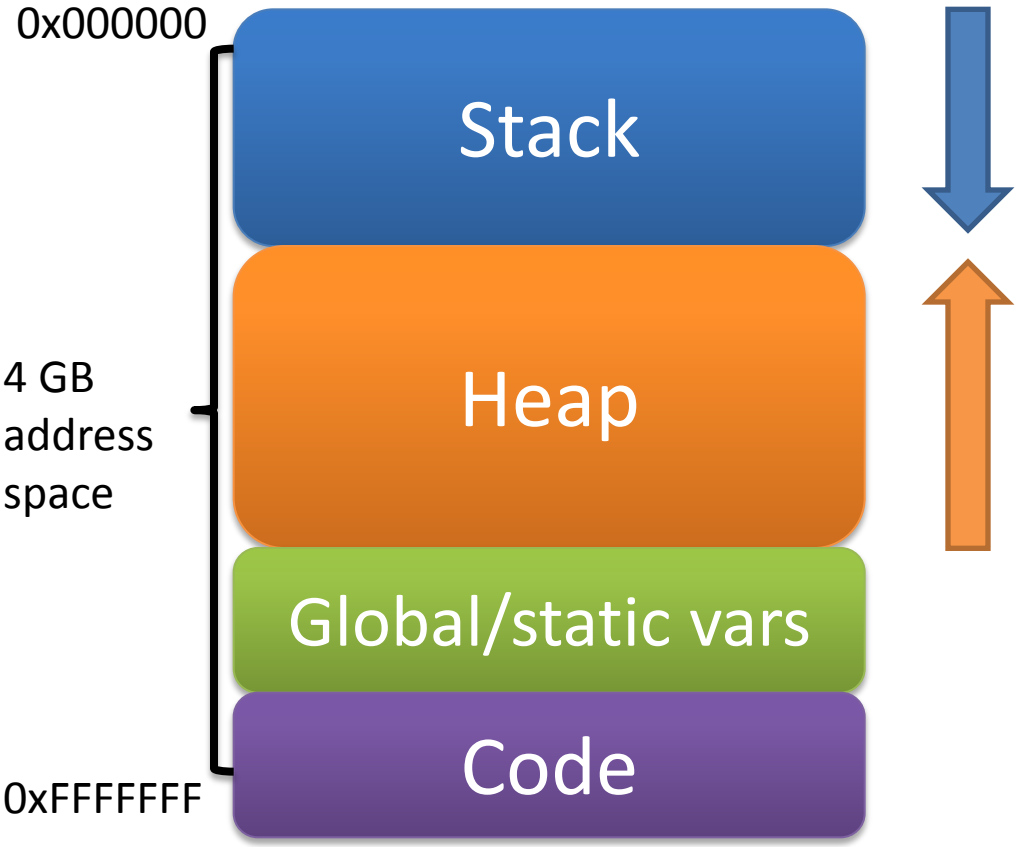
Memory

- each process gets its own memory chunk, or ***address space***



Memory

- each process gets its own memory chunk, or ***address space***



Stack Allocation

- memory allocated by the program as it runs
  - local variables
  - function calls
- fixed at compile time

Heap Allocation

- dynamic memory allocation
  - memory allocated at run-time

- two options for allocating memory:
  - **`malloc()`**
  - **`calloc()`**
    - both require **`#include <stdlib.h>`** to work

malloc()

```
void* malloc ( <size to be allocated> )
```

```
char *letters;
letters = (char*) malloc(userVariable *
                         sizeof(char));
```

- malloc returns a pointer to a ***contiguous*** block memory of the size requested

calloc()

```
void* calloc ( <number of elements>,
               <size of type> )

float *grades;
grades = (float*) calloc(userVariable,
                         sizeof(float));
```

- calloc works very similarly to malloc, but it initializes all the allocated bits to zero
  - takes longer than malloc, so only use if needed

Casting Allocated Memory

- both **`calloc()`** and **`malloc()`** return a pointer of type **`void`**, so you must cast the memory to match the given type

```
letters = (char*) malloc(userVariable *
                         sizeof(char));

grades = (float*) calloc(userVariable,
                         sizeof(float));
```

Casting Allocated Memory

- both **`calloc()`** and **`malloc()`** return a pointer of type **`void`**, so you must cast the memory to match the given type

```
letters = (char*) malloc(userVariable *
                         sizeof(char));

grades = (float*) calloc(userVariable,
                         sizeof(float));
```

Handling Allocated Memory

- **IMPORTANT**: before using allocated memory make sure it's *actually been allocated*

- if memory wasn't correctly allocated, the address that is returned will be **`null`**
  - this means there isn't a contiguous block of memory large enough to handle request

Exiting in Case of NULL

- if the address returned is **`null`**, your program should exit
  - **`exit()`** takes an integer value
  - non-zero values are used as error codes

```
if (grades == NULL) {
   printf("Memory not allocated,
           exiting.\n");
   exit(-1);
}
```

Managing Your Memory

- ***stack*** allocated memory is automatically freed when functions **`return`**
  - including **`main()`**

- memory on the ***heap*** was allocated by you – so it must also be freed by you

Freeing Memory

- done using the **`free()`** function
  - free takes a pointer as an argument:

```
free(grades);
free(letters);
```

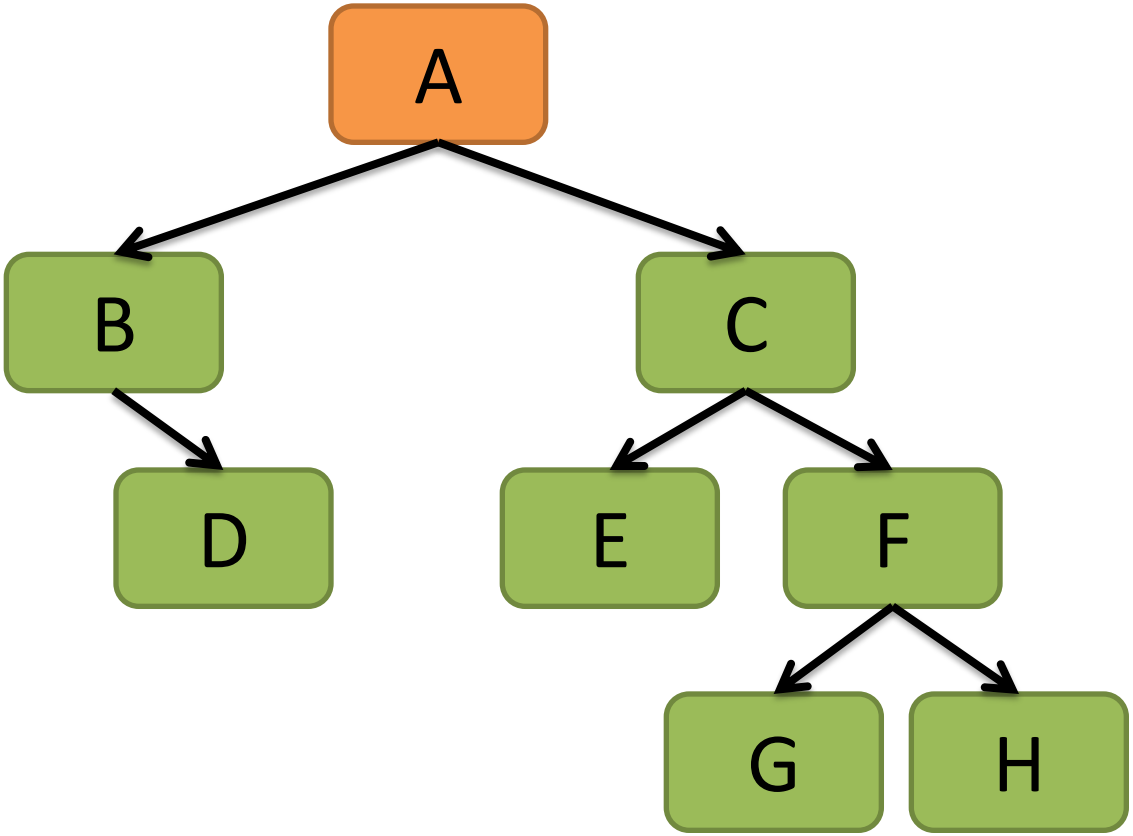
- **`free()`** does not work recursively
  - for each individual allocation, there must be an individual call to free that allocated memory
  - called in a sensible order

Freeing in Order

In what order would you free the nodes of this linked list?

Freeing in Order

In what order would you free the nodes of this binary tree?



Outline

- (from last class) Testing
- Memory allocation
- Memory errors
- Errors
- Debugging
- Homeworks

Memory Errors

- when we dynamically allocate memory, we are handling it directly
- have to be aware of possible errors like:
  - accessing off-limits memory
  - “losing” memory
  - running out of memory
    - not common nowadays, except in some embedded systems

Memory Leaks

- ***memory leaks*** occur when data is continually dynamically allocated but not freed

- access to the memory is then "lost"
  - for example, a loop that re-allocates memory to the same variable without freeing

- eventually we will run out of memory, and the program will crash or forcefully exit

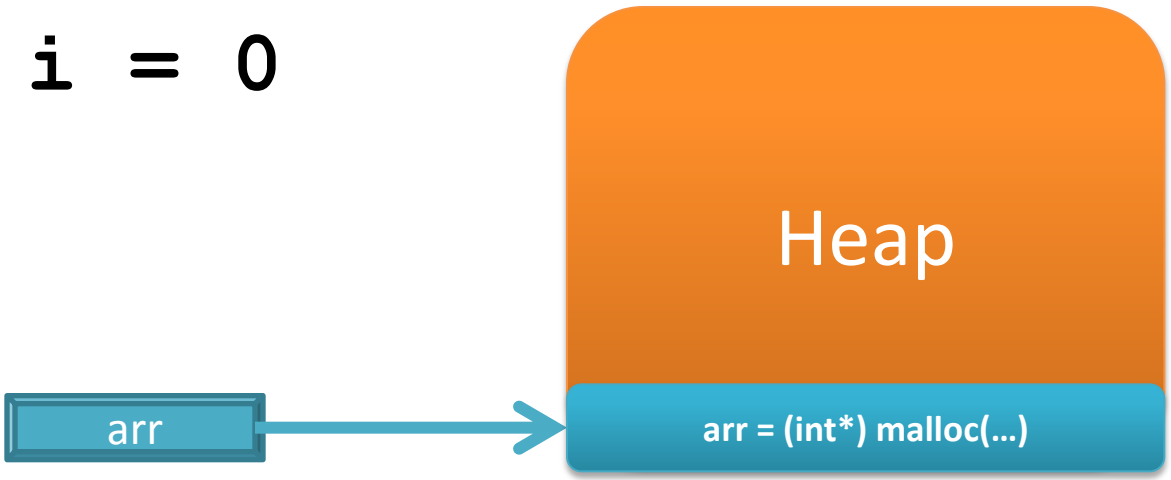
Memory Leak Example

```
for (i = 0; i < var; i++) {
  arr = (int*) malloc(NUM * sizeof(int));
  /* check if arr == NULL */
}
```

Memory Leak Example

```
for (i = 0; i < var; i++) {
  arr = (int*) malloc(NUM * sizeof(int));
  /* check if arr == NULL */
}
```

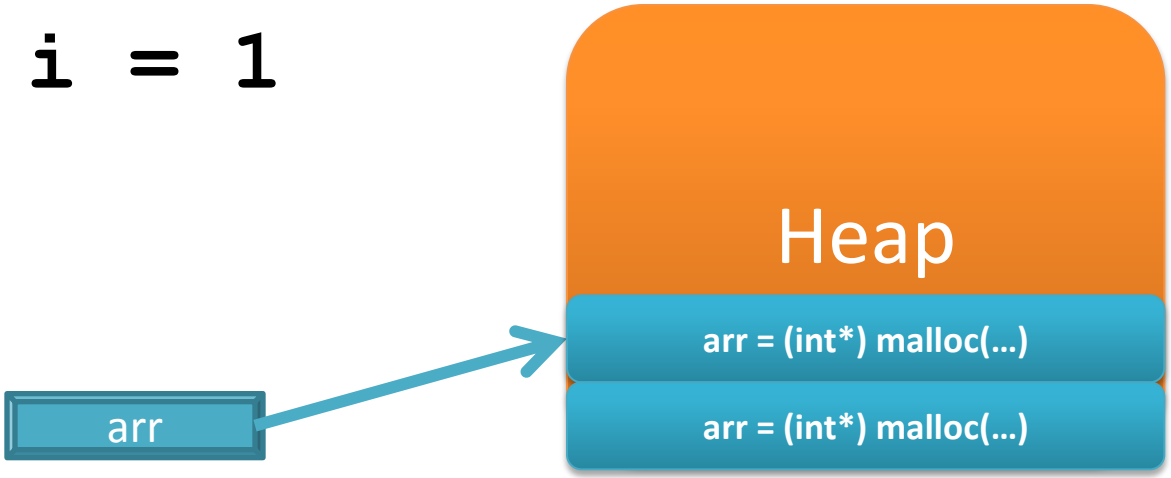
i = 0



Memory Leak Example

```
for (i = 0; i < var; i++) {
  arr = (int*) malloc(NUM * sizeof(int));
  /* check if arr == NULL */
}
```

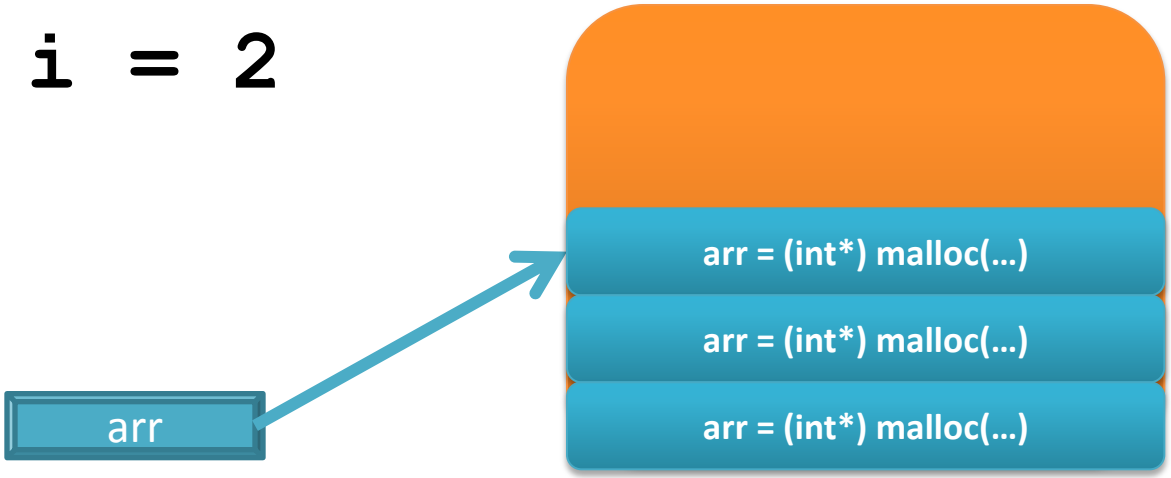
i = 1



Memory Leak Example

```
for (i = 0; i < var; i++) {
  arr = (int*) malloc(NUM * sizeof(int));
  /* check if arr == NULL */
}
```

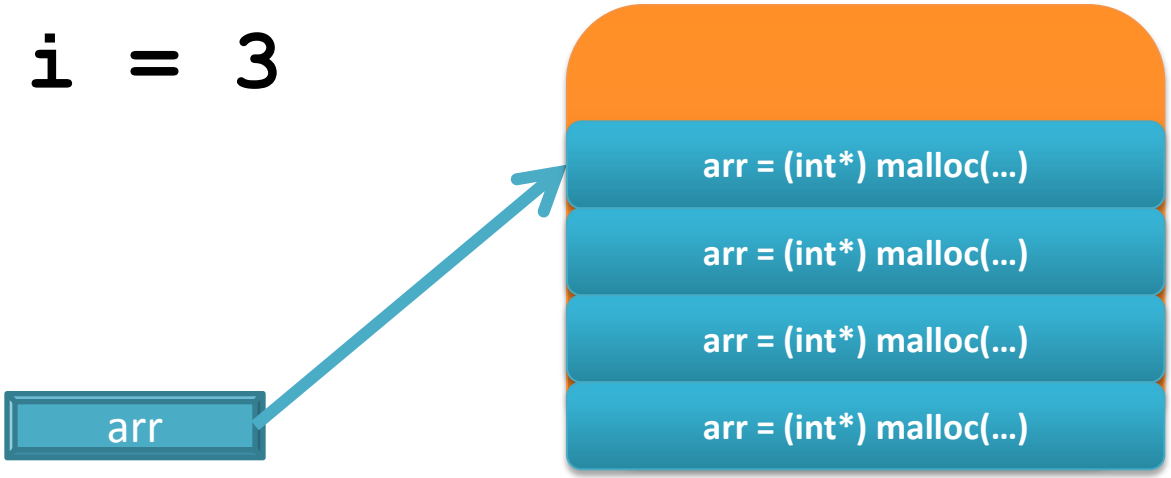
i = 2



Memory Leak Example

```
for (i = 0; i < var; i++) {
  arr = (int*) malloc(NUM * sizeof(int));
  /* check if arr == NULL */
}
```

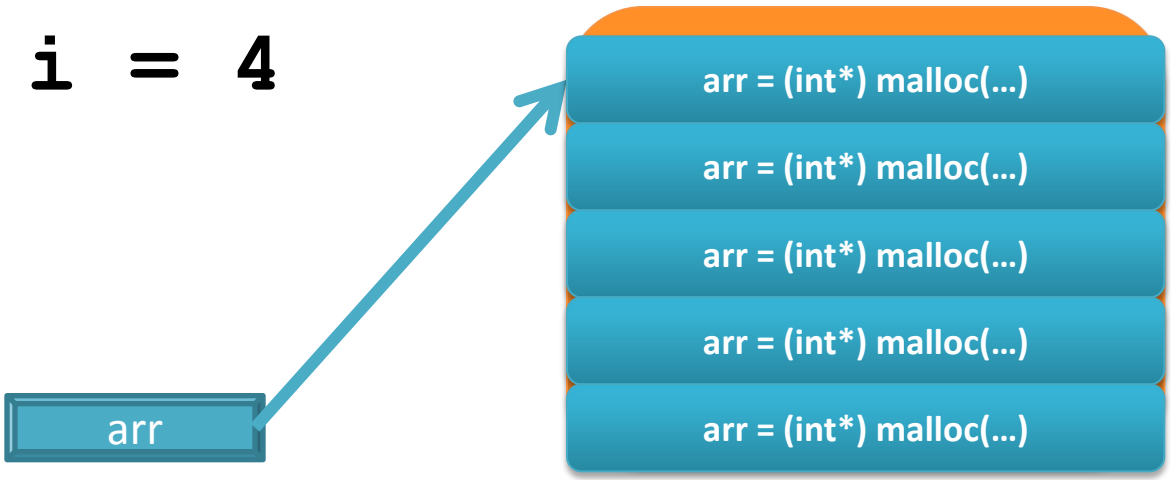
i = 3



Memory Leak Example

```
for (i = 0; i < var; i++) {
  arr = (int*) malloc(NUM * sizeof(int));
  /* check if arr == NULL */
}
```

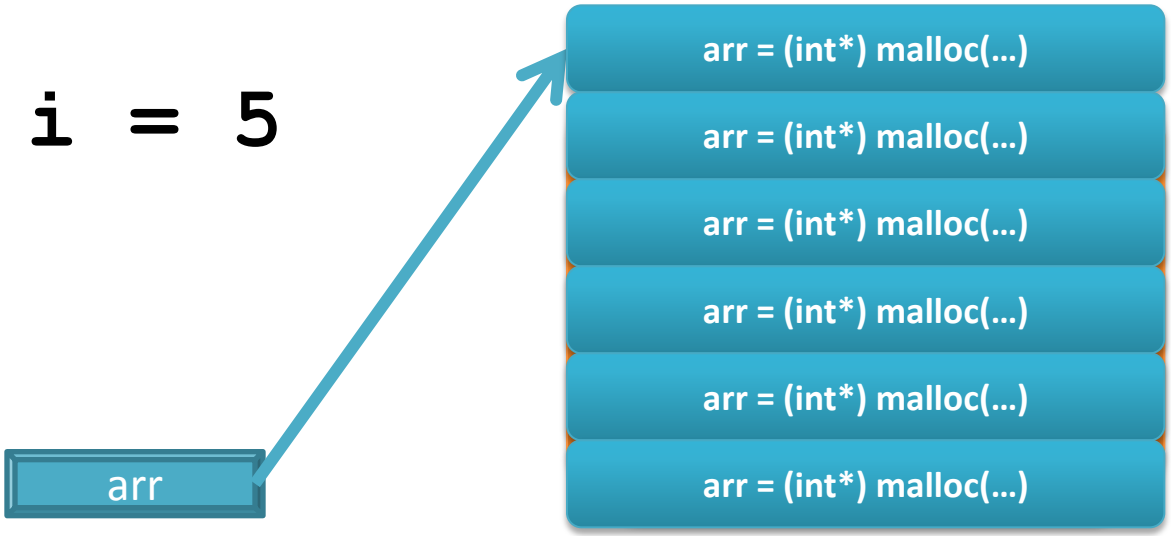
i = 4



Memory Leak Example

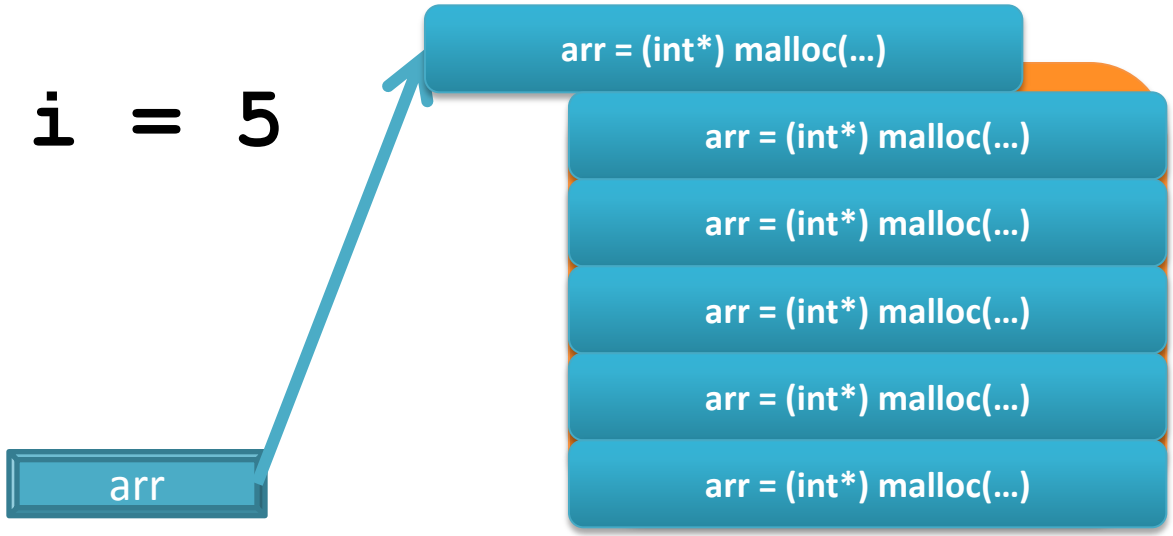
```
for (i = 0; i < var; i++) {
  arr = (int*) malloc(NUM * sizeof(int));
  /* check if arr == NULL */
}
```

i = 5



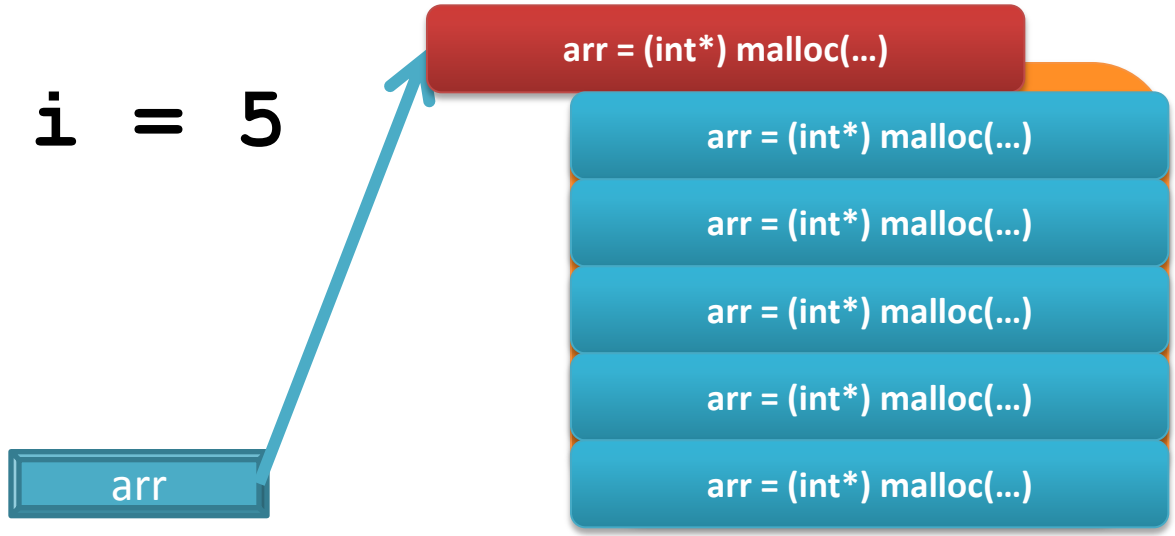
Memory Leak Example

```
for (i = 0; i < var; i++) {
   arr = (int*) malloc(NUM * sizeof(int));
   /* check if arr == NULL */
}
```



Memory Leak Example

```
for (i = 0; i < var; i++) {
   arr = (int*) malloc(NUM * sizeof(int));
   /* check if arr == NULL */
}
```



Mistakes When Using free()

- ***double free***
  - freeing one pointer twice
    - without reallocating memory in-between frees
  - can cause a segfault

- ***dangling pointer***
  - a pointer that points to freed memory
  - trying to access can cause a segfault

Segmentation Faults

- ***segmentation faults*** occur when you try to access memory that is off-limits

- segfaults occur during a program's runtime
  - this can make them difficult to debug

Common Causes of Segfaults

- accessing out-of-bounds on an array
- accessing the memory address of uninitialized pointers
- accessing a pointer whose address points to memory that has been freed

C Trying to Be “Nice”

- when it can, C will do its best to shield you from errors like
  - freeing memory twice
  - accessing freed memory
  - manipulating freed memory
- but not
  - using uninitialized memory

C Being Nice

- double free memory
  - C will let it silently fail (most of the time)

- accessing freed memory
  - C will let you do this (most of the time)
  - BUT….

Killing with Kindness

- the data that was stored there has degraded or been corrupted when it was freed

- if code is changed so that freed memory is overwritten by a new “legitimate” allocation
  - you will suddenly have errors
  - that aren’t caused by the new code
  - makes it very difficult to debug

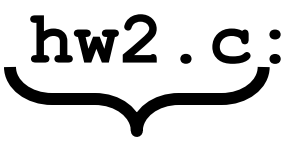
Outline

- (from last class) Testing
- Memory allocation
- Memory errors
- Errors
- Debugging
- Homeworks

Understanding Errors

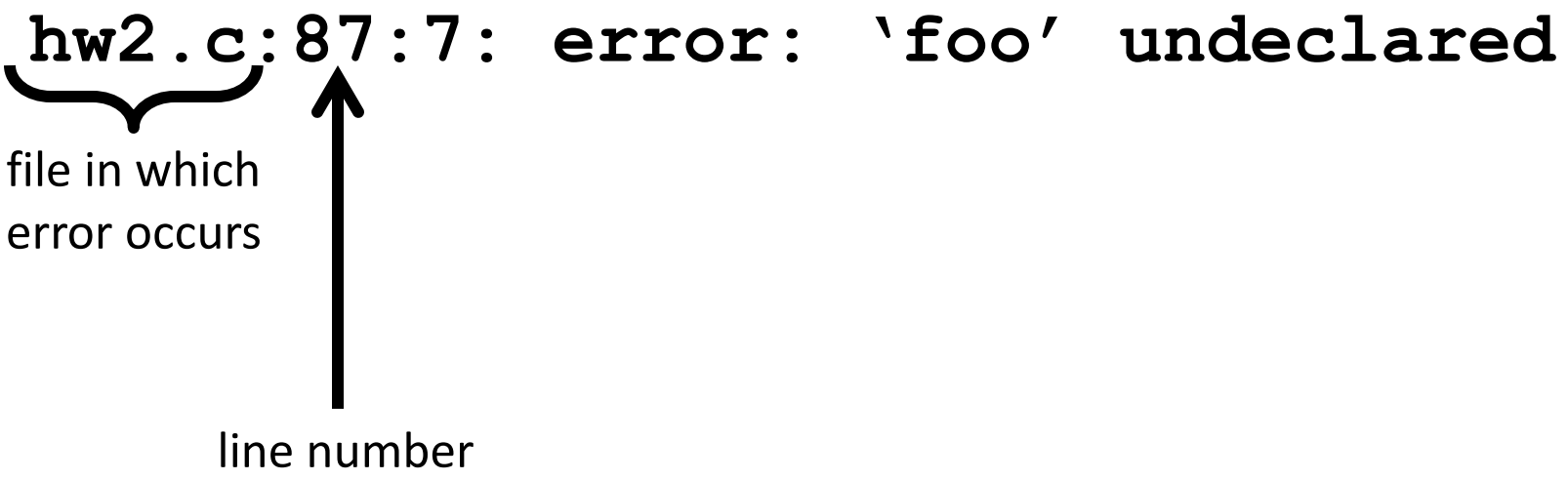
```
hw2.c:87:7: error: ‘foo’ undeclared
```

Understanding Errors

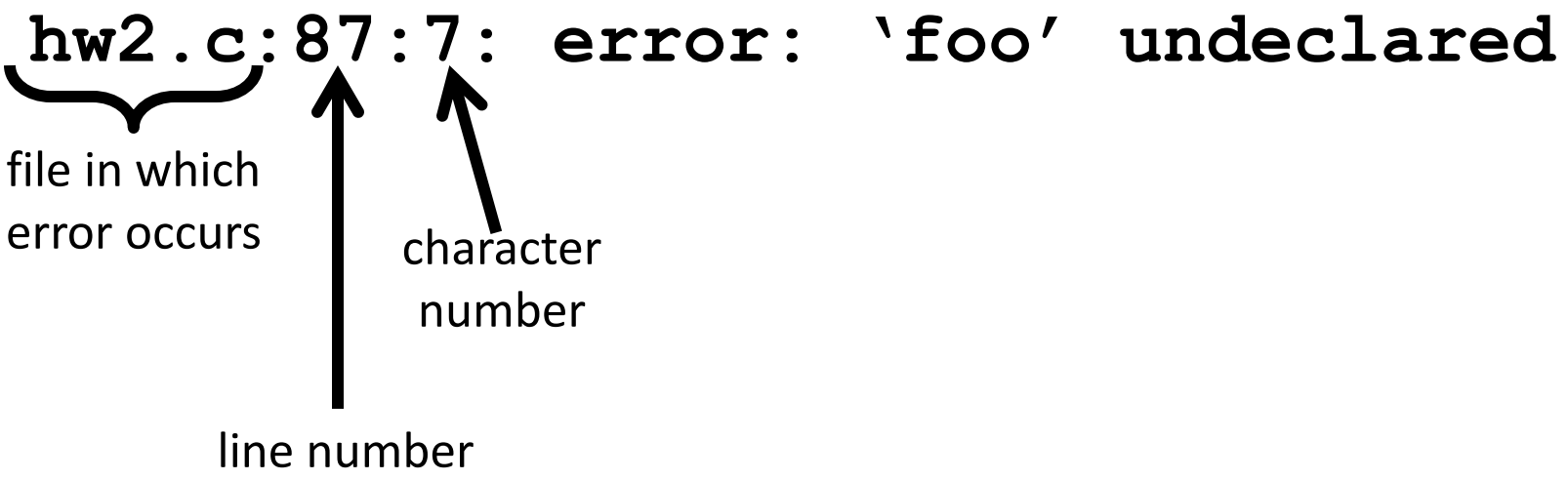


file in which
error occurs

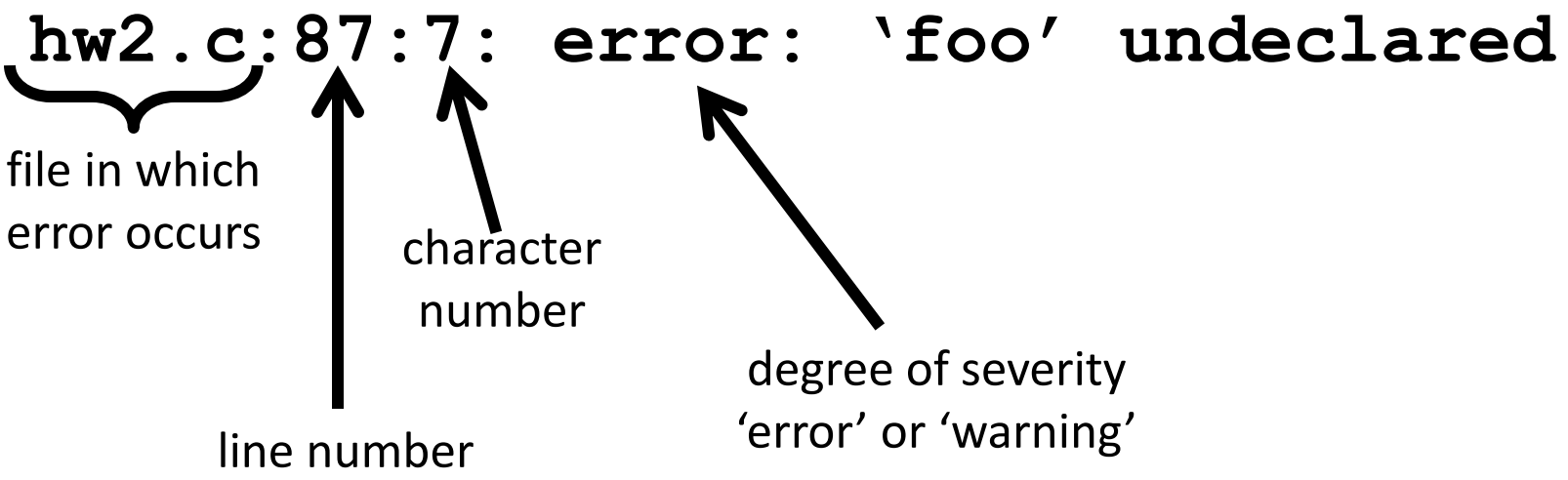
Understanding Errors



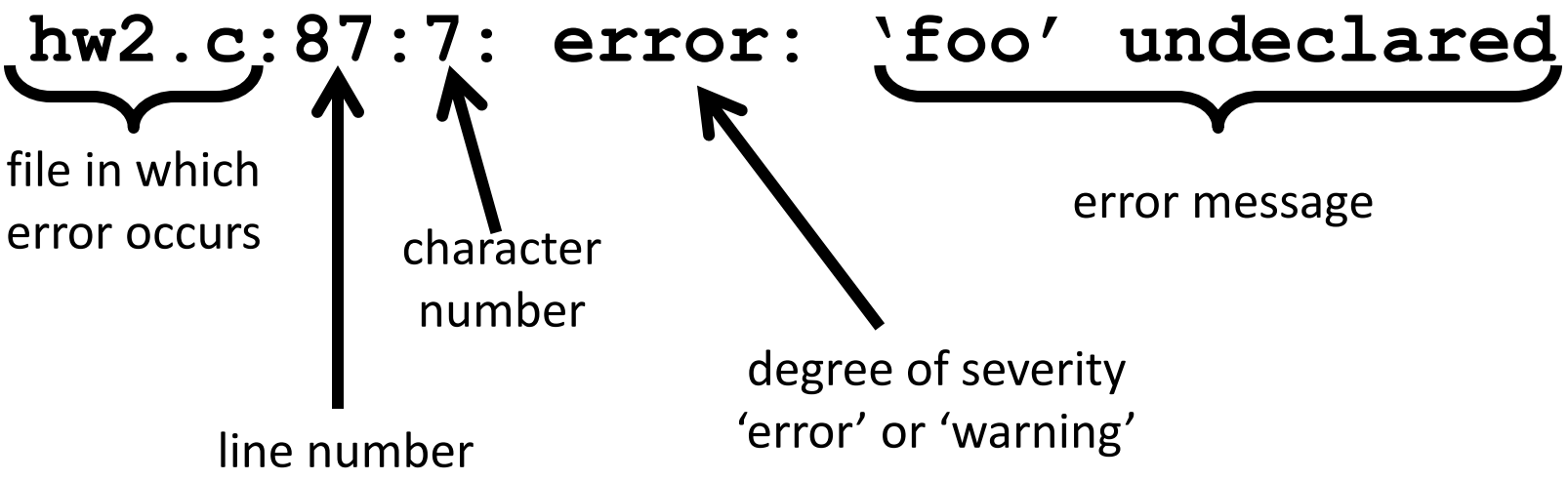
Understanding Errors



Understanding Errors



Understanding Errors



#1 Rule of Debugging

- start with the **very first** error or warning

- recompile every time an error is fixed
  - errors will cascade
  - and de-cascade when fixed!

Cascading Errors

```
int numStudnts;
for (i = 0; i < numStudents; i++) {
   total += grades[i];
}
avg = total/numStudents;
```

Cascading Errors

```
int numStudnts;
for (i = 0; i < numStudents; i++) {
   total += grades[i];
}
avg = total/numStudents;
```

```
> gcc -Wall average.c
```

Cascading Errors

```
int numStudnts;
for (i = 0; i < numStudents; i++) {
   total += grades[i];
}
avg = total/numStudents;
```

```
> gcc -Wall average.c
```

- the **-Wall** flag shows all of warnings

Cascading Errors

```
int numStudnts;
for (i = 0; i < numStudents; i++) {
  total += grades[i];
}
avg = total/numStudents;
```

```
> gcc -Wall average.c
average.c:5:5: warning: unused variable ‘numStudnts’
average.c:22:17: error: ‘numStudents’ undeclared
average.c:25:13: error: ‘numStudents’ undeclared
```

Cascading Errors

```
int numStudnts;
for (i = 0; i < numStudents; i++) {
   total += grades[i];
}
avg = total/numStudents;
```

```
> gcc -Wall average.c
average.c:5:5: warning: unused variable ‘numStudnts’
average.c:22:17: error: ‘numStudents’ undeclared
average.c:25:13: error: ‘numStudents’ undeclared
```

Cascading Errors

```
int numStudnts;
for (i = 0; i < numStudents; i++) {
   total += grades[i];
}
avg = total/numStudents;
```

```
> gcc -Wall average.c
average.c:5:5: warning: unused variable 'numStudnts'
average.c:22:17: error: 'numStudents' undeclared
average.c:25:13: error: 'numStudents' undeclared
```

Cascading Errors

```
int numStudents;
for (i = 0; i < numStudents; i++) {
   total += grades[i];
}
avg = total/numStudents;
```

Cascading Errors

```
int numStudents;
for (i = 0; i < numStudents; i++) {
   total += grades[i];
}
avg = total/numStudents;

> gcc -Wall average.c
```

Cascading Errors

```
int numStudents;
for (i = 0; i < numStudents; i++) {
   total += grades[i];
}
avg = total/numStudents;
```

```
> gcc -Wall average.c
```

- got rid of all 3 errors!

When Errors Occur

- compile time
  - pretty easy (normally typos or simple mistakes)
- linking
  - slightly harder (could be easy, could require rethinking how your code is laid out)
- run time
  - UGH (often difficult to pinpoint, and sometimes hard to spot at all)
  - best bet is to use a debugger

Common Compiler Errors

`hw2.c:87:7: error: ‘foo’ undeclared`

- if **`foo`** is a **variable**:
  - forgot to declare
  - misspelled (on declaration or on use)
- if **`foo`** is a **function**:
  - forgot to #include file containing the prototype
  - misspelled (on declaration or on use)

Common Compiler Errors

```
hw2.c:37:6: warning: unused variable
    ‘bar’
```

- variable was declared but not used
  - normally because variable declaration has a typo
  - if you’re in the midst of writing code, this warning may be *temporarily* acceptable
    - haven’t had a chance to use the variable yet

Common Compiler Errors

```
hw2.c:54: warning: suggest
    parentheses around assignment
    used as truth value
```

- often a mistake inside a control statement
  - you meant to use **==** not **=**
  - (you want equivalency, not assignment)

Common Compiler Errors

```
hw2.c: 51: error: expected ';'
    before 'for'
```

- missing semicolon on previous line of code
- 'for' is simply the word directly following the missing semicolon
  - could be 'int' or 'if' or a variable name, etc

Common Linker Errors

```
hw4.o: In function ‘main’:
hw4.c:91: undefined reference to ‘Fxn’
```

- linker can’t find code for ‘Fxn’ in any .o file
  - forgot to link **`.o`** file
  - misspelled named of Fxn
  - parameter list is different
    - differences between prototype/definition/call

Common Linker Errors

```
/usr/lib64/gcc/[...]/crt1.o: In function
    `_start':
/home/[...]/start.S:119: undefined
    reference to main
```

- you compiled a file that does not contain a **`main()`**
- without using the **`-c`** flag to indicate separate compilation

ABSOLUTELY TERRIFYING ERROR

- (story time!)

ABSOLUTELY TERRIFYING ERROR

```
> gcc -Wall structs.c
In file included from /usr/include/stdio.h:33:0,
                 from structs.c:6:
/usr/lib64/gcc/x86_64-suse-linux/4.7/include/stddef.h:213:1: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'typedef'
In file included from /usr/include/stdio.h:74:0,
                 from structs.c:6:
/usr/include/libio.h:307:3: error: unknown type name 'size_t'
/usr/include/libio.h:311:67: error: 'size_t' undeclared here (not in a function)
/usr/include/libio.h:339:62: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/libio.h:348:6: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/libio.h:470:19: error: expected '=', ',', ';', 'asm' or '__attribute__' before '_IO_sgetn'
In file included from structs.c:6:0:
/usr/include/stdio.h:319:35: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:325:47: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:337:20: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:344:10: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:386:44: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:390:45: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:666:11: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:669:9: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:679:8: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:709:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'fread'
/usr/include/stdio.h:715:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'fwrite'
/usr/include/stdio.h:737:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'fread_unlocked'
/usr/include/stdio.h:739:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'fwrite_unlocked'
In file included from structs.c:9:0:
/usr/include/string.h:43:8: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:46:56: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:55:18: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:62:42: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:65:56: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:92:48: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:129:39: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:137:9: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:143:57: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:150:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strxfrm'
In file included from structs.c:9:0:
/usr/include/string.h:165:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strxfrm_l'
/usr/include/string.h:180:45: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:281:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strcspn'
/usr/include/string.h:285:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strspn'
/usr/include/string.h:395:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strlen'
/usr/include/string.h:402:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strnlen'
/usr/include/string.h:423:12: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:447:33: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:451:53: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:455:31: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:458:54: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:536:61: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:573:34: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:576:39: error: expected declaration specifiers or '...' before 'size_t'
In file included from structs.c:11:0:
/usr/include/stdlib.h:139:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before '__ctype_get_mb_cur_max'
In file included from structs.c:11:0:
/usr/include/stdlib.h:331:4: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:361:4: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:465:22: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:467:22: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:467:38: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:479:36: error: expected declaration specifiers or '...' before 'size_t'
In file included from /usr/include/stdlib.h:491:0,
                 from structs.c:11:
/usr/include/alloca.h:32:22: error: expected declaration specifiers or '...' before 'size_t'
In file included from structs.c:11:0:
/usr/include/stdlib.h:497:22: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:502:45: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:502:65: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:755:9: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:755:25: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:760:34: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:760:50: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:839:6: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:842:6: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:846:31: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:850:31: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:859:36: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:863:34: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:870:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'mbstowcs'
/usr/include/stdlib.h:873:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'wcstombs'
```

ABSOLUTELY TERRIFYING ERROR

```
> gcc -Wall structs.c
In file included from /usr/include/stdio.h:33:0,
                 from structs.c:6:
/usr/lib64/gcc/x86_64-suse-linux/4.7/include/stddef.h:213:1: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'typedef'
In file included from /usr/include/stdio.h:74:0,
                 from structs.c:6:
/usr/include/libio.h:307:3: error: unknown type name 'size_t'
/usr/include/libio.h:311:67: error: 'size_t' undeclared here (not in a function)
/usr/include/libio.h:339:62: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/libio.h:348:6: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/libio.h:470:19: error: expected '=', ',', ';', 'asm' or '__attribute__' before '_IO_sgetn'
In file included from structs.c:6:0:
/usr/include/stdio.h:319:35: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:325:47: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:337:20: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:344:10: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:386:44: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:390:45: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:666:11: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:669:9: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:679:8: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdio.h:[illegible]: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'fwrite'
/usr/include/stdio.h:[illegible]: error: expected '=', ',', ';', 'asm' or '__attribute__' before '_unlocked'
/usr/include/stdio.h:[illegible]: error: expected '=', ',', ';', 'asm' or '__attribute__' before
In file included from st
/usr/include/string.h:[illegible]: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:46:56: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:55:18: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:62:42: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:65:56: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:92:48: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:129:39: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:137:9: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:143:57: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:150:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strxfrm'
In file included from structs.c:9:0:
/usr/include/string.h:165:15: error: expected [illegible], ';', 'asm' or '__attribute__' before 'strxfrm_l'
/usr/include/string.h:180:45: error: expected [illegible]ration specifiers or '...' before 'size_t'
/usr/include/string.h:2[illegible]: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strcspn'
/usr/include/string.h:285:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strspn'
/usr/include/string.h:395:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strlen'
/usr/include/string.h:402:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'strnlen'
/usr/include/string.h:423:12: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:447:33: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:451:53: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:455:31: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:458:54: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:536:61: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:573:34: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/string.h:576:39: error: expected declaration specifiers or '...' before 'size_t'
In file included from structs.c:11:0:
/usr/include/stdlib.h:139:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before '__ctype_get_mb_cur_max'
In file included from structs.c:11:0:
/usr/include/stdlib.h:331:4: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:361:4: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:465:22: [illegible] declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:[illegible]: error: exp[illegible]tion specifiers or '...' before 'size_t'
/usr/include/stdlib.h:4[illegible]: error: expe[illegible] declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:479:[illegible]: error: expe[illegible] declaration specifiers or '...' before 'size_t'
In file included from /usr/include/stdlib.h:491:0,
                 from structs.c:11:
/usr/include/locale.h:32:22: error: expected declaration specifiers or '...' before 'size_t'
In file included from structs.c:11:0:
/usr/include/stdlib.h:497:22: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:502:45: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:502:65: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:755:9: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:755:25: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:760:34: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:760:50: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:839:6: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:842:6: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:846:31: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:850:31: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:859:36: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:863:34: error: expected declaration specifiers or '...' before 'size_t'
/usr/include/stdlib.h:870:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'mbstowcs'
/usr/include/stdlib.h:873:15: error: expected '=', ',', ';', 'asm' or '__attribute__' before 'wcstombs'
```

EASY TO FIX

Debugging Basics

- if the error's not clear from just looking at the code, you can try:

- inserting probe statements with printf
  - (but adding a printf might change your error!)
- rubber duck debugging
- Googling the error message
- using a debugger

Outline

- (from last class) Testing
- Memory allocation
- Memory errors
- Errors
- Debugging
- Homeworks

Debuggers

- see what is going on “inside” the program
  - more powerful and accurate than printf() probes
- examine individual variables (value & address)
  - can change variable’s value on the fly
- step through code line by line
  - can skip blocks of code you don’t want to see

Using DDD (or GDB)

- must use the '**-g**' flag when compiling

- open program for testing using command line:

```
ddd a.out
gdb hw2
```

- GDB – Gnu Project Debugger (text based)
- DDD – Data Display Debugger (GUI based)

LIVECODING

DDD Basics

- debugger allows you to:

- add breakpoints to stop the program at specific points
- use ‘print’ or ‘display’ to show values (or addresses) of variables
- step through code line by line

LIVECODING

DDD Tips

- File -> Open Source
  - choose a different file to look at (and to set breakpoints in)
- Source -> Reload Source
  - refresh the source you're using after recompiling without losing any breakpoints or data displays
- FINISH
  - executes the current "frame"
  - will pause when it hits a return (outside of main)

LIVECODING

DDD Livecoding

- DDD livecoding example was taken wholesale from the sample session on this page:

http://www.gnu.org/software/ddd/manual/html_mono/ddd.html

- site also has more information about DDD

LIVECODING

Outline

- (from last class) Testing
- Memory allocation
- Memory errors
- Errors
- Debugging
- Homeworks

Homework 2

- due tomorrow night @ midnight
- if you haven’t started yet – do it NOW!

Homework 3

- Memory Diagrams

- write legibly
- double check your work

- due at BEGINNING of class, on paper
  - no late days for this homework!