CSc 352
Object Files, Executables, Linking

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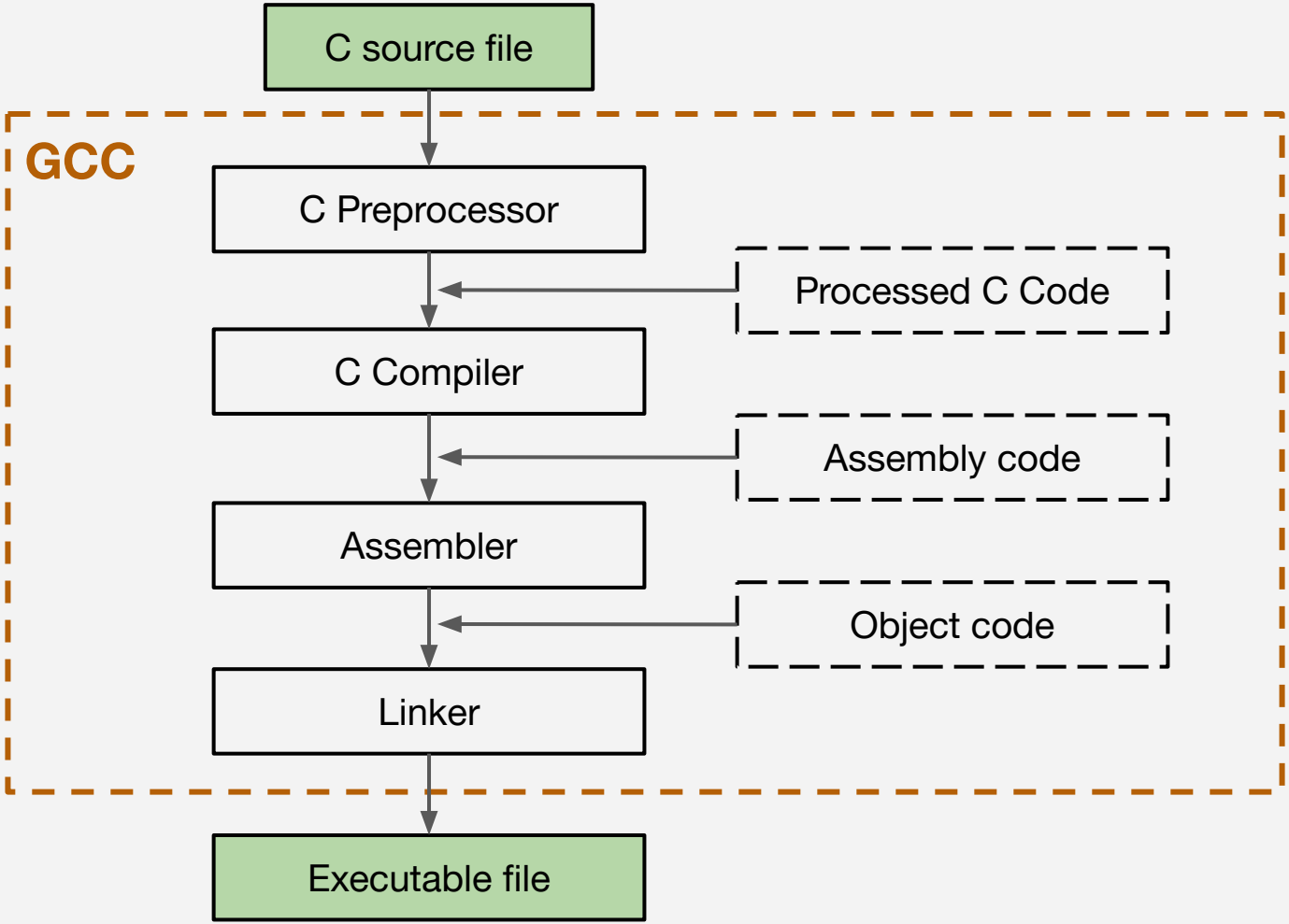
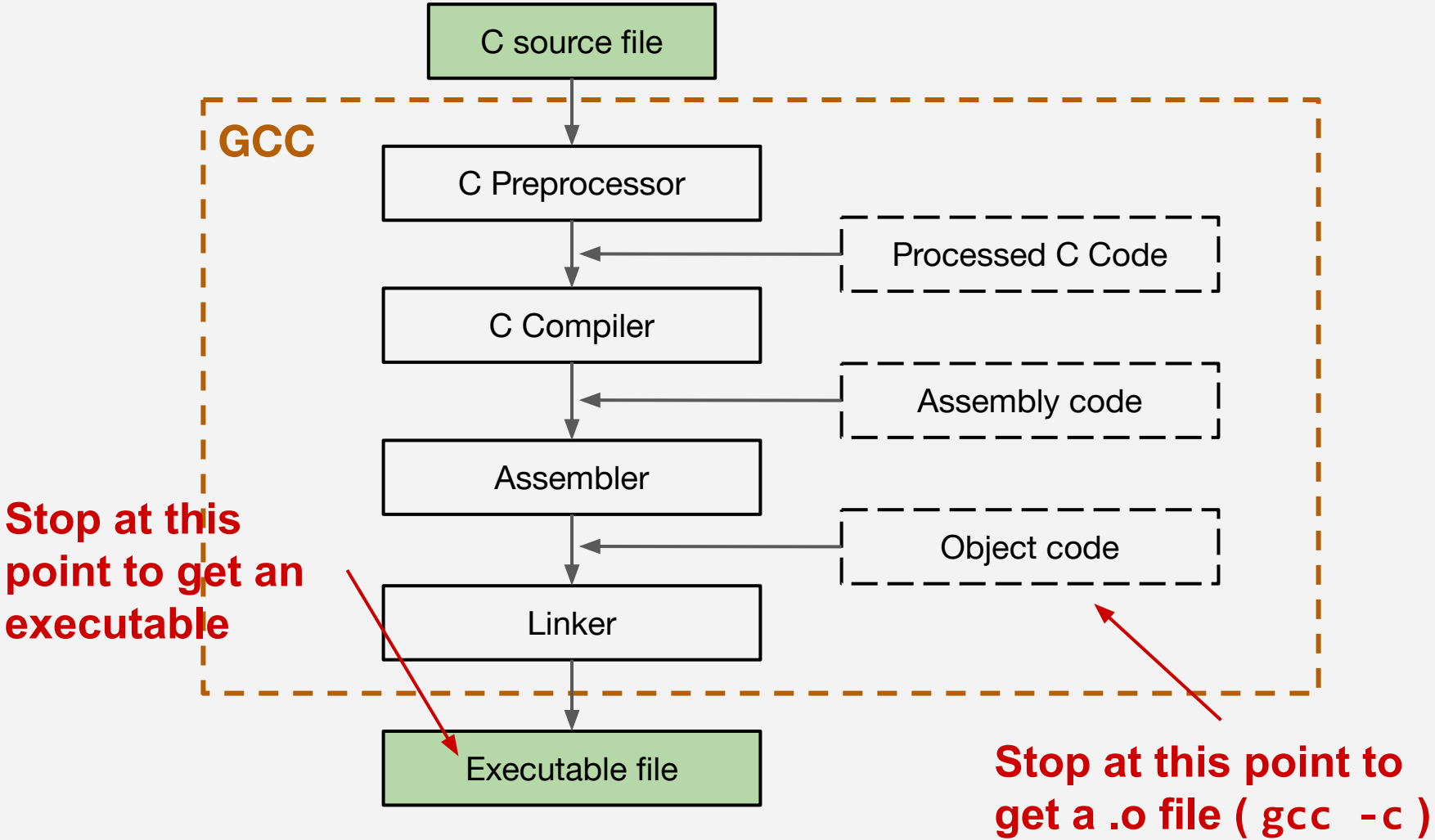
Compiling to Bytecode

- When we compile a program with GCC, the eventual goal is to get binary code
  - Either executable, or object file (to be linked with other code)


C source file
GCC
C Preprocessor
Processed C Code
C Compiler
Assembly code
Assembler
Object code
Linker
Executable file


C source file
GCC
C Preprocessor
Processed C Code
C Compiler
Assembly code
Assembler
Object code
Linker
Executable file
Stop at this point to get an executable
Stop at this point to get a .o file (gcc -c)

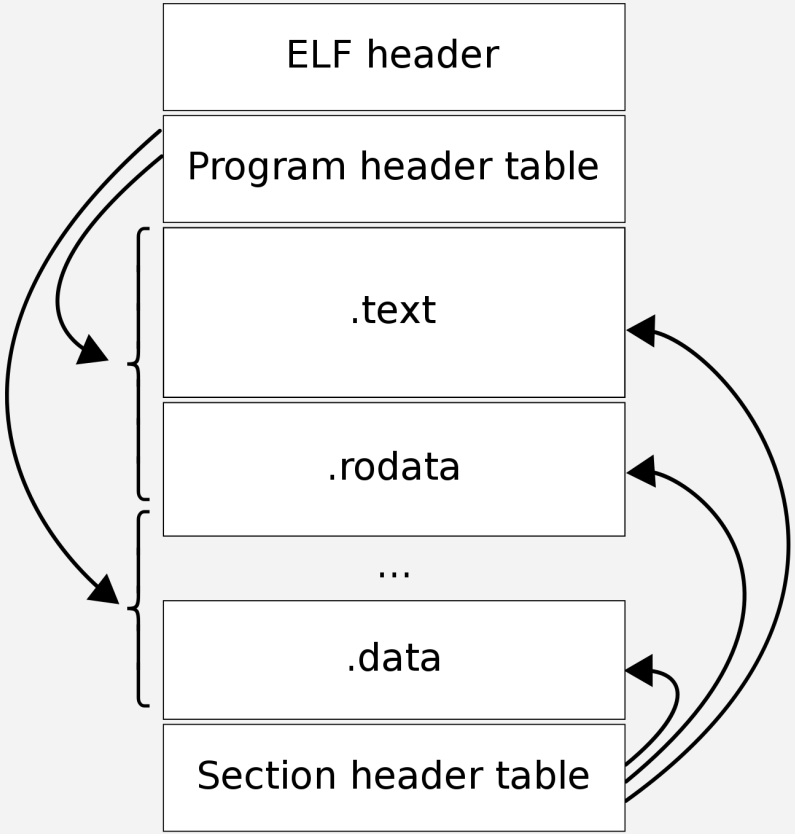
Going through the steps

```
$ gcc test.c -E -o /tmp/test.i
$ gcc /tmp/test.i -S -o /tmp/test.s
$ as /tmp/test.s -o /tmp/test.o
$ ld /tmp/test.o
$ objdump -D -t /tmp/test.o > /tmp/test.d
```

https://medium.com/@kunaljaydesai/understanding-linking-8709e2cc450e
https://medium.com/swlh/deep-dive-into-static-linking-c3b1f459c99d

ELF

- Executable and Linkable Format (ELF) is the standard format used for executable files and object files on UNIX systems
- The ELF format specifies where various parts of the program go (the code, the constants, the symbol table, etc)
- Remember: Files are just a bunch of 1s and 0s - We can choose how to interpret these files!



https://en.wikipedia.org/wiki/Executable_and_Linkable_Format

Reading ELF Files

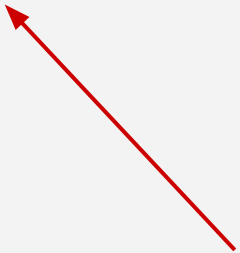
- **`objdump -s`** Display full contents in hex
- **`objdump -d -S`** Display disassembled code, with source intermixed
- **`readelf -h`** Display the header info
- **`readelf -a`** Display all the info

Explore with a simple file

```c
#include <stdio.h>
int main() {
  printf("sup\n");
  return 0;
}
```

From output of objdump

```
0000000000001149 <main>:
#include <stdio.h>
int main() {
    1149: f3 0f 1e fa           endbr64
    114d: 55                    push   %rbp
    114e: 48 89 e5              mov    %rsp,%rbp
  printf("sup\n");
    1151: 48 8d 3d ac 0e 00 00  lea    0xeac(%rip),%rdi        # 2004 <_IO_stdin_used+0x4>
    1158: e8 f3 fe ff ff        callq  1050 <puts@plt>
  return 0;
    115d: b8 00 00 00 00        mov    $0x0,%eax
}
    1162: 5d                    pop    %rbp
    1163: c3                    retq
    1164: 66 2e 0f 1f 84 00 00  nopw   %cs:0x0(%rax,%rax,1)
    116b: 00 00 00
    116e: 66 90                 xchg   %ax,%ax
```

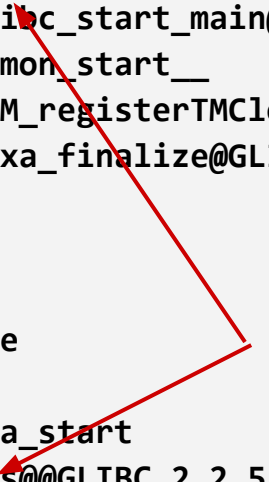


What happens when we call a standard library function?

From output of readelf -a

```
Symbol table '.dynsym' contains 7 entries:
   Num:    Value          Size Type    Bind   Vis      Ndx Name
     0: 0000000000000000     0 NOTYPE  LOCAL  DEFAULT  UND
     1: 0000000000000000     0 NOTYPE  WEAK   DEFAULT  UND _ITM_deregisterTMCloneTab
     2: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND puts@GLIBC_2.2.5 (2)
     3: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND __libc_start_main@GLIBC_2.2.5 (2)
     4: 0000000000000000     0 NOTYPE  WEAK   DEFAULT  UND __gmon_start__
     5: 0000000000000000     0 NOTYPE  WEAK   DEFAULT  UND _ITM_registerTMCloneTable
     6: 0000000000000000     0 FUNC    WEAK   DEFAULT  UND __cxa_finalize@GLIBC_2.2.5 (2)


. . .
Symbol table '.symtab' contains 70 entries:
   Num:    Value          Size Type    Bind   Vis      Ndx Name
. . .
    53: 0000000000004000     0 NOTYPE  WEAK   DEFAULT   25 data_start
    54: 0000000000000000     0 FUNC    GLOBAL DEFAULT  UND puts@@GLIBC_2.2.5
    55: 0000000000004010     0 NOTYPE  GLOBAL DEFAULT   25 _edata
```



Compare and Contrast

Take the test program and compile in two ways:

```
$ gcc -Wall -Werror -std=c11 -g test.c -o dynamic
$ gcc -static -Wall -Werror -std=c11 -g test.c -o static
```

What is the difference?

Investigate with **objdump** and **readelf**

```c
#include <stdio.h>
int main() {
  printf("sup\n");
  return 0;
}
```

Compare and Contrast

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What is the difference?

Investigate with **objdump** and **readelf**

```c
#include <stdio.h>
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Compare and Contrast

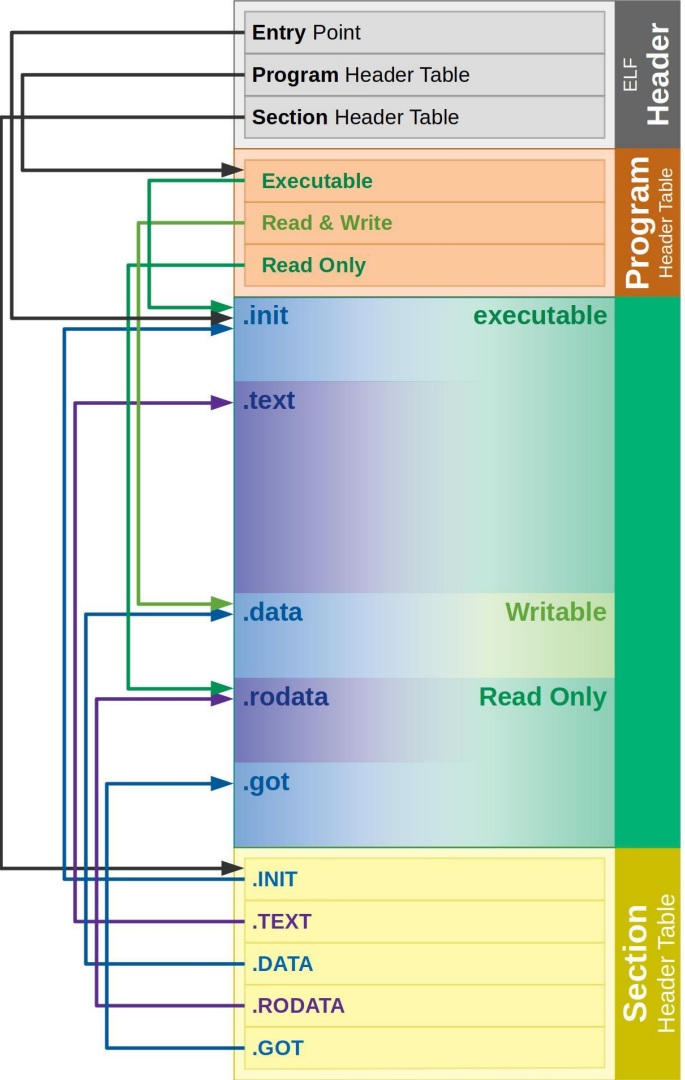
Take the test program and compile in two ways:

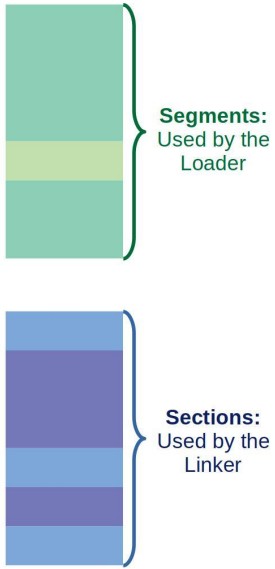
```
$ gcc -Wall -Werror -std=c11 -c test.c -o dynamic.o
$ gcc -Wall -Werror -std=c11 test.c -o dynamic
```

What is the difference?

Investigate with **objdump** and **readelf**

```c
#include <stdio.h>
int main() {
  printf("sup\n");
  return 0;
}
```





https://www.ics.uci.edu/~aburtsev/238P/hw/hw3-elf/hw3-elf.html

Linking

- In the **linking** step, combining code from multiple ELF files together If needed)
- Can link from other .o file that are a part of your project
- Can also link to other shared object files, such as the standard library

Static and Dynamic Linking

- In **Static Linking** the code from the file being linked together is actually included in the executable (larger file size)
- With **Dynamic linking**, the other symbols (functions, data) are dynamically linked at **runtime**

Load a program

```c
#include <stdio.h>
#include <unistd.h>
int main() {
  printf("me!\n");
  char* arguments[] = {NULL};
  char* environment[] = {NULL};
  int value = execve("./a.out", arguments, environment);
  if (value == -1) {
    printf("Failed to execute\n");
  }
  return 0;
}
```

Thank You!