Summary Chapter 7

Alexandre David

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Credits to R.E. Bryant and D.R. Hallaron from CMU

Example C Program

main.c

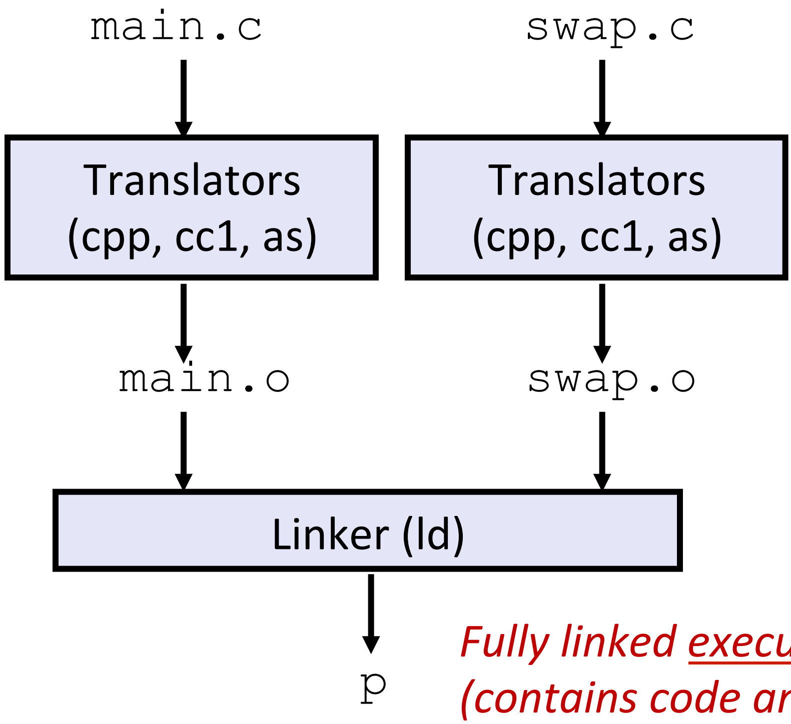
```c
int buf[2] = {1, 2};

int main()
{
   swap();
   return 0;
}
```

swap.c

```c
extern int buf[];

int *bufp0 = &buf[0];
static int *bufp1;

void swap()
{
   int temp;

   bufp1 = &buf[1];
   temp = *bufp0;
   *bufp0 = *bufp1;
   *bufp1 = temp;
}
```

Static Linking

- Programs are translated and linked using a *compiler driver*:
  - `unix> gcc -O2 -g -o p main.c swap.c -static`
  - `unix> ./p`



Source files

Separately compiled relocatable object files

Fully linked executable object file (contains code and data for all functions defined in `main.c and swap.c`)

Why Linkers?

- Reason 1: Modularity
  - Program can be written as a collection of smaller source files, rather than one monolithic mass.
  - Can build libraries of common functions (more on this later)
    - e.g., Math library, standard C library

Why Linkers? (cont)

- Reason 2: Efficiency
  - Time: Separate compilation
    - Change one source file, compile, and then re-link.
    - No need to recompile other source files.
  - Space: Libraries
    - Common functions can be aggregated into a single file...
    - Yet executable files and running memory images contain only code for the functions they actually use.

What Do Linkers Do?

- Step 1. Symbol resolution

  - Programs define and reference *symbols* (variables and functions):
    - `void swap() {…}    /* define symbol swap */`
    - `swap();            /* reference symbol a */`
    - `int *xp = &x;      /* define symbol xp, reference x */`

  - Symbol definitions are stored (by compiler) in *symbol table*.
    - Symbol table is an array of structs
    - Each entry includes name, size, and location of symbol.

What Do Linkers Do? (cont)

- Step 2. Relocation
  - Merges separate code and data sections into single sections
  - Relocates symbols from their relative locations in the `.o` files to their final absolute memory locations in the executable.
  - Updates all references to these symbols to reflect their new positions.

Three Kinds of Object Files (Modules)

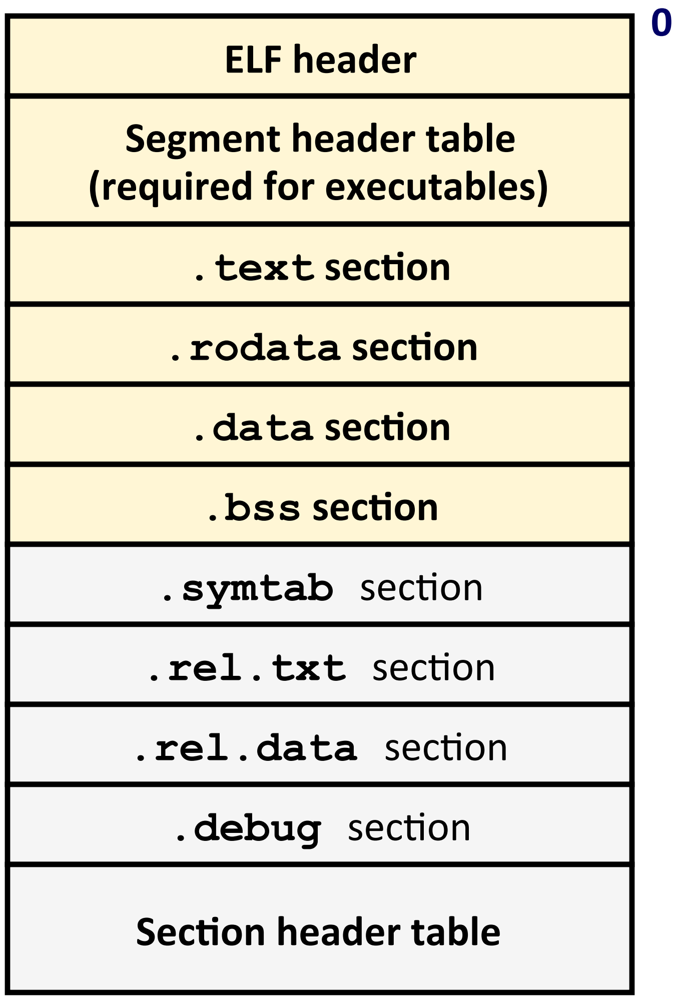
- Relocatable object file (`.o` file)
  - Contains code and data in a form that can be combined with other relocatable object files to form executable object file.
    - Each `.o` file is produced from exactly one source (`.c`) file
- Executable object file (`a.out` file)
  - Contains code and data in a form that can be copied directly into memory and then executed.
- Shared object file (`.so` file)
  - Special type of relocatable object file that can be loaded into memory and linked dynamically, at either load time or run-time.
  - Called *Dynamic Link Libraries* (DLLs) by Windows

Executable and Linkable Format (ELF)

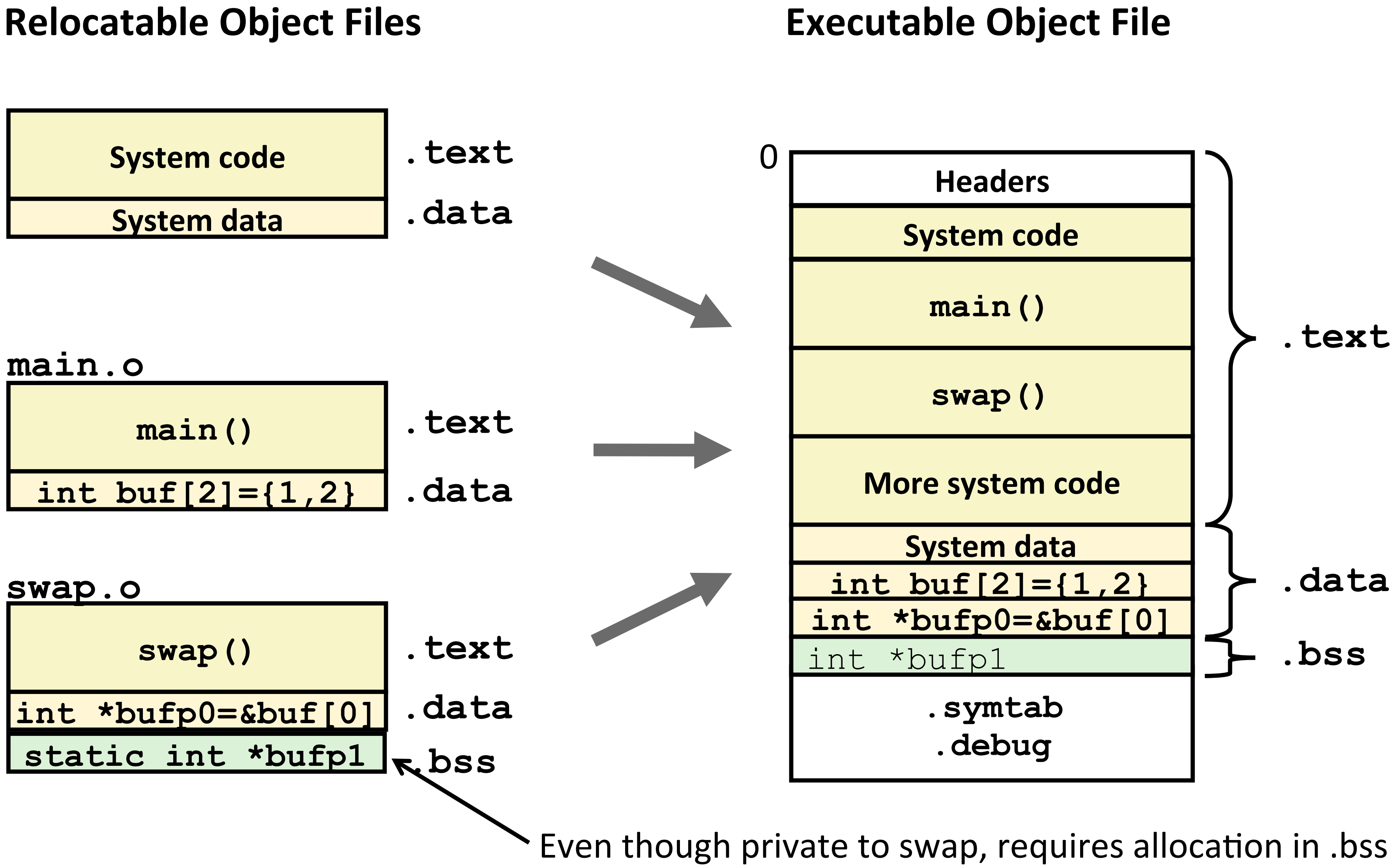
- Standard binary format for object files
- Originally proposed by AT&T System V Unix
  - Later adopted by BSD Unix variants and Linux
- One unified format for
  - Relocatable object files (`.o`),
  - Executable object files (`a.out`)
  - Shared object files (`.so`)
- Generic name: ELF binaries

ELF Object File Format

- Elf header
  - Word size, byte ordering, file type (.o, exec, .so), machine type, etc.
- Segment header table
  - Page size, virtual addresses memory segments (sections), segment sizes.
- `.text` section
  - Code
- `.rodata` section
  - Read only data: jump tables, ...
- `.data` section
  - Initialized global variables
- `.bss` section
  - Uninitialized global variables
  - "Block Started by Symbol"
  - "Better Save Space"
  - Has section header but occupies no space



Relocating Code and Data



Remember

- At compile time, the compiler does not know where some functions are.
- At run time, the processor needs the address in memory.
- In between, someone has to resolve that. It can be done statically or dynamically.