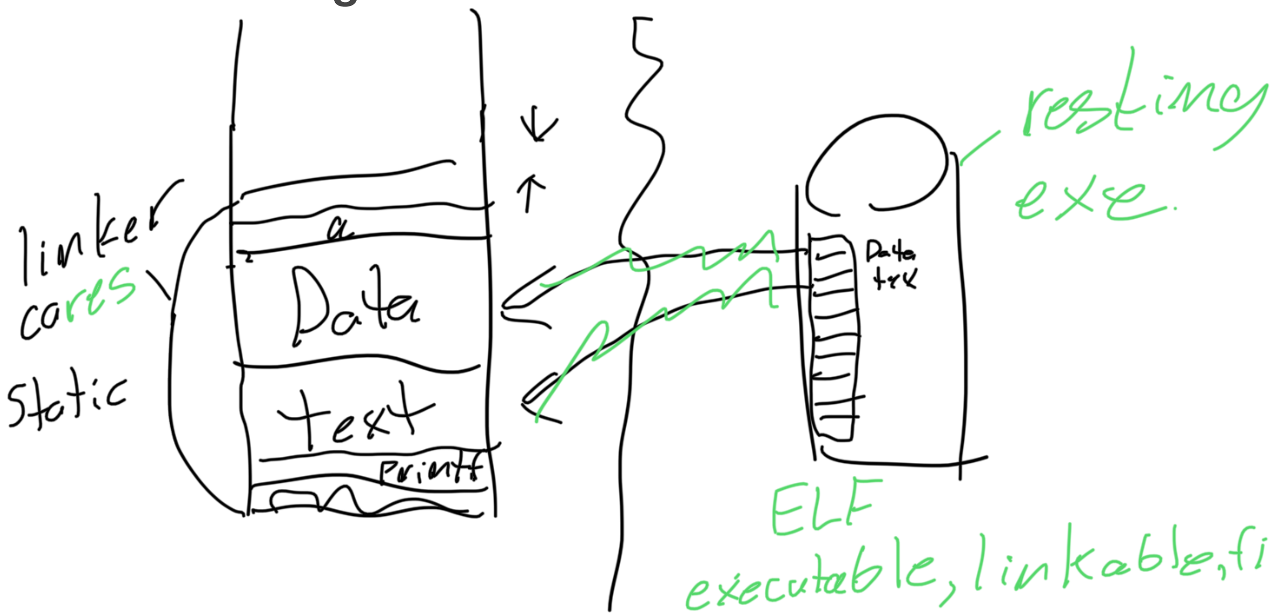
Slides 3 - Linking



$a0 = "Hello world"

printf( ) → jal printf - external reference

printf.c → printf( )

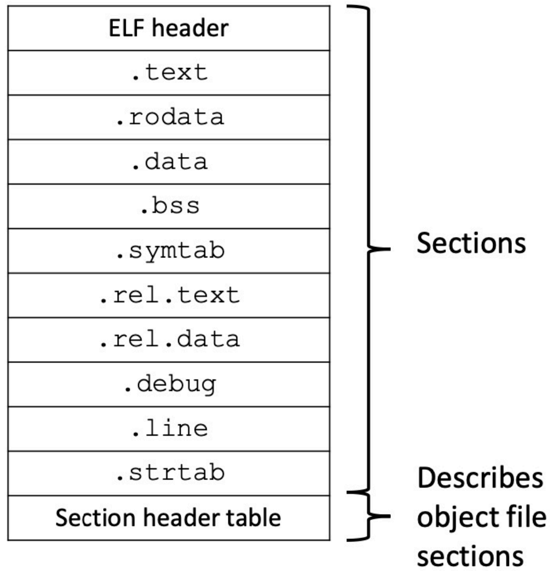
Symbol address never changes

L Stored in static memory

ao zz

Executable and Linkable Format

- ELF header
  - Word size
  - Byte ordering
  - Machine type (e.g., IA32)
  - ELF header size
  - Object file type
    relocatable, executable, or shared
  - Offset of the section header
  - Number of entries
- Section header table
  - Section locations and sizes
  - A fixed size entry for each



main.c → main.o

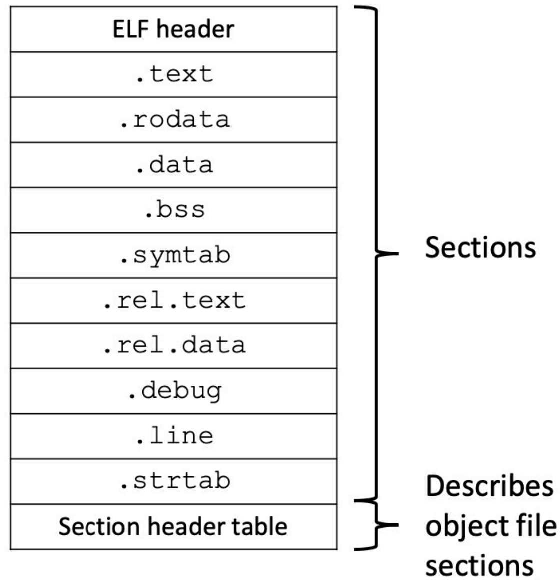
a.out

.dll, .so

a.out is just a file, when executed, it loads data into memory

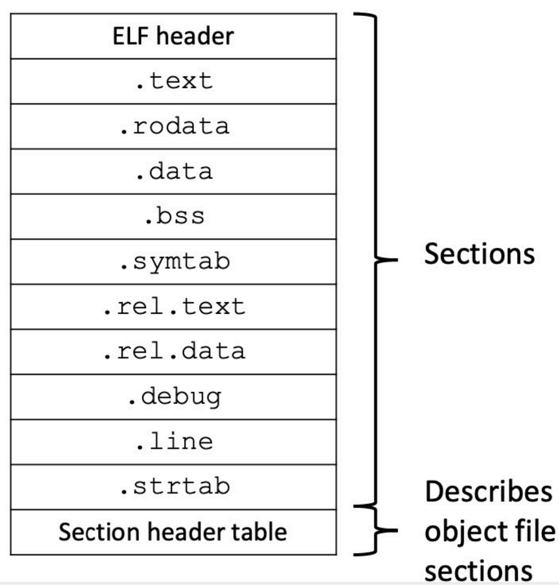
Executable and Linkable Format

- .text section
  - Machine instructions
- .data section
  - Initialized global variables
  - Static local variables
- .bss (Block storage start) section
  - Uninitialized global variables
- .symtab
  - Symbol table
  - Functions and global variables



ELF Format

- .rel.text section – offset from zero
  - Relocation info for .text section
- .rel.data section
  - Relocation info for .data section
- .debug section (gcc –g)
  - Symbolic debugging information
- .line section
  - Mapping line # in source code and machine instruction in the .text section
- .strtab section
  - String table for .symtab and .debug



ELF Symbol Examples

```
/* main.c */
void swap();

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

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

Num:	Value	Size	Type	Bind	Ndx	Name
8:	0	8	OBJECT	GLOBAL	3	buf
9:	0	21	FUNC	GLOBAL	1	main
10:	0	0	NOTYPE	GLOBAL	UND	swap

```
/* swap.c */
extern int buf[];

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

void swap(){
        int temp;
        bufp1 = &buf[1];
        temp = *bufp0;
        *bufp0 = *bufp1;
        *bufp1 = temp;
}
```

Num:	Value	Size	Type	Bind	Ndx	Name
8:	0	4	OBJECT	GLOBAL	3	bufp0
9:	0	0	NOTYPE	GLOBAL	UND	buf
10:	8	4	OBJECT	GLOBAL	COM	bufp1
11:	0	59	FUNC	GLOBAL	1	swap

Additional Example

```
<swap.c>
extern int buf[];

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

static void incr () {
    static int count=0;
    int i=0;
    count++;
}

void swap () {
    int temp;

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

buf:	external global, undefined	
bufp0:	global,	.data
bufp1:	local,	.bss
count:	local,	.data
incr:	local,	.text
swap:	global,	.text

objdump -S *.o — gives instruction

cross-compiler

Strong and Weak Symbols

- Symbols are either *strong* and *weak*
  - Strong – Functions and initialized global variables
  - Weak – uninitialized global variables
  - Complier exports global symbols to the assembler (weak or strong)
  - Assembler encode symbols information in .symtab

```
                 p1.c                  p2.c

Strong  <------- int foo = 5           int foo;       -------> Weak

Strong  <------- int p1 () {           int p2 () {    -------> Strong
Weak?   <------------ int a;                int b = 5 -------> Strong?
                 }                     }
```

If there's two of the same strong symbols, there will be a linking error

Symbol Resolution

- **Rule 1** – Multiple strong symbols are not allowed
- **Rule 2** – Given a strong symbol and multiple weak symbols, choose the strong symbol
- **Rule 3** – Given multiple weak symbols, choose any of the weak symbols

Relocation

- After the symbol resolution
  - Linker associates each symbol reference in the code with exactly one symbol definition
  - Linker knows the exact sizes of the code and data sections

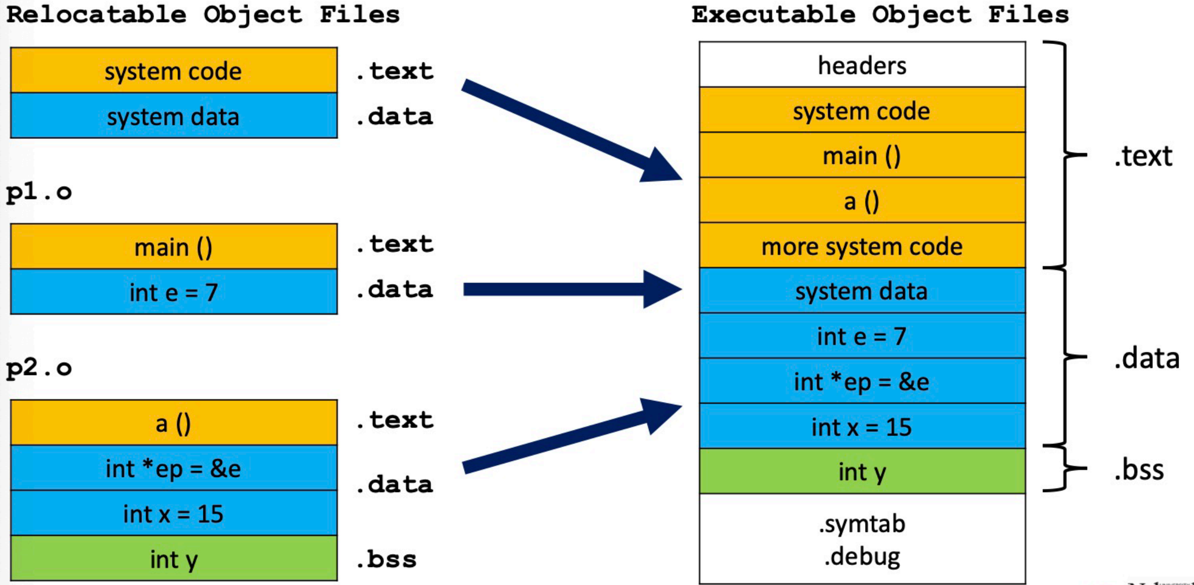
1. Relocating sections and symbol definitions
   - Merging all sections of the same type
   - Assigning run-time memory address
2. Relocating symbol reference within sections
   - Update External references to point to the correct address

Relocation Example

```
p1.c

int e = 7;

int main () {
      int r = a();
      exit (0);
}
```

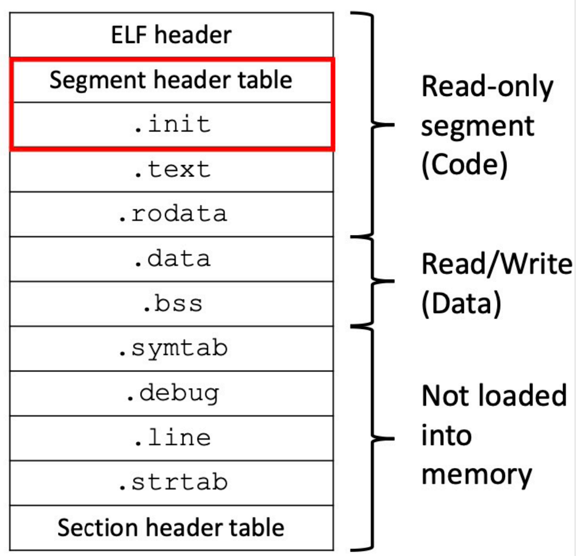
```
p2.c

extern int e;

int *ep = &e;
int x = 15;
int y;

int a () {
      return *ep+x+y;
}
```

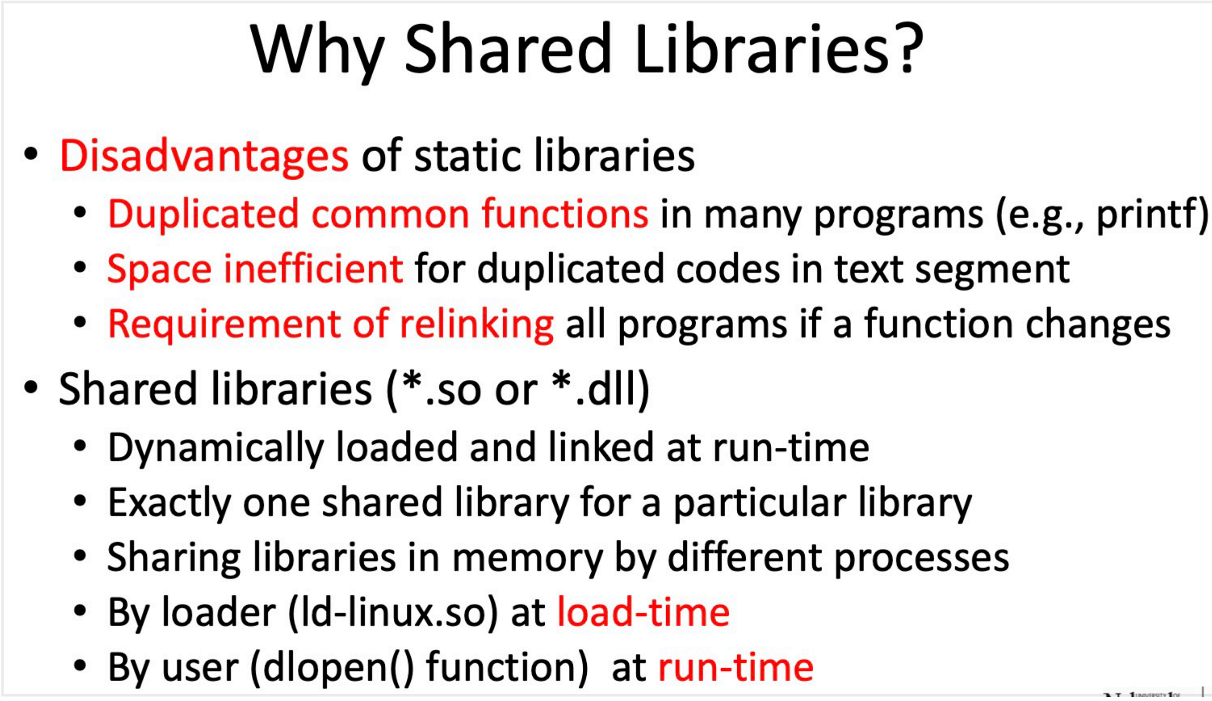
Relocating Sections



Executable Object Format

- Fully linked (relocated)
  - no .rel sections needed
- Segment header Table
  - Page size
  - Virtual and physical address of memory segments (sections)
  - Segment sizes
- .init
  - Called by programs' initialization code





Dynamic library can be used at runtime