Systems and Internet Infrastructure Security

Institute for Networking and Security Research
Department of Computer Science and Engineering
Pennsylvania State University, University Park, PA

Introduction to C (Part 1)

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(adapted from original slides by Steve Gribble at UWash)

Assignment #2

- Getting your feet wet with C
- See website
- Due February 7
- Any major problems – talk to me!

Unix utilities: tar

- `tar` collects multiple files and directory data in a single file
  - Archive, like Zip or RAR
  - `tar` just puts the files together
  - It uses other programs to compress
- The resulting single file is frequently called a tarball.
  - Common extensions: .tar.gz, .tgz, .tar.bz2, .tbz

tar usage

`tar -x -v -z -f file.tar.gz`

- `-x`: extract from an archive
- `-v`: verbose (show info/filenames)
- `-z`: uncompress the tarball with gzip
- `-f`: read the archive from this file
- PROTIP: combine short options `-xvzf` and save keystrokes! (see below)

`tar -cvzf file.tar.gz <files>`

- `-c`: create an archive
- `-v`: verbose
- `-z`: compress the tarball with gzip
- `-f`: output the archive to this file
- `<files>`: list of files and directories to store

C workflow

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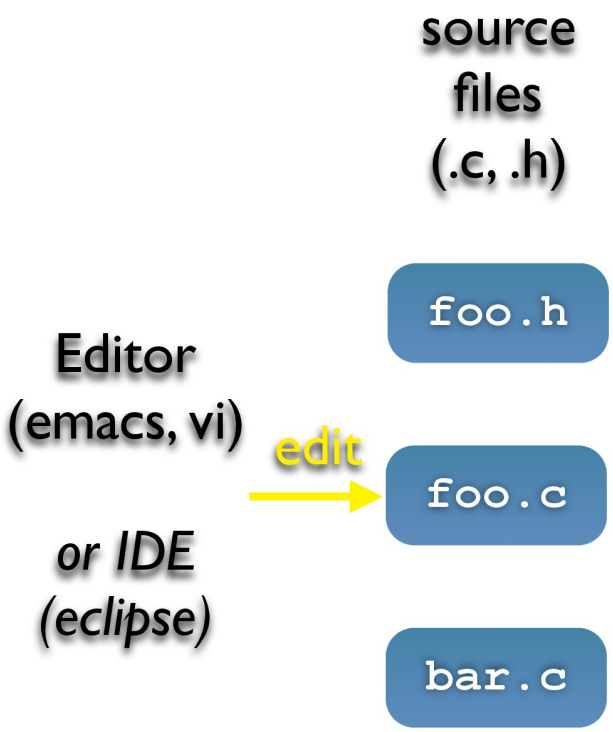
1 8 5 5

Editor
(emacs, vi)

or IDE
(eclipse)

C workflow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(.c, .h)
foo.h
Editor
(emacs, vi)
edit
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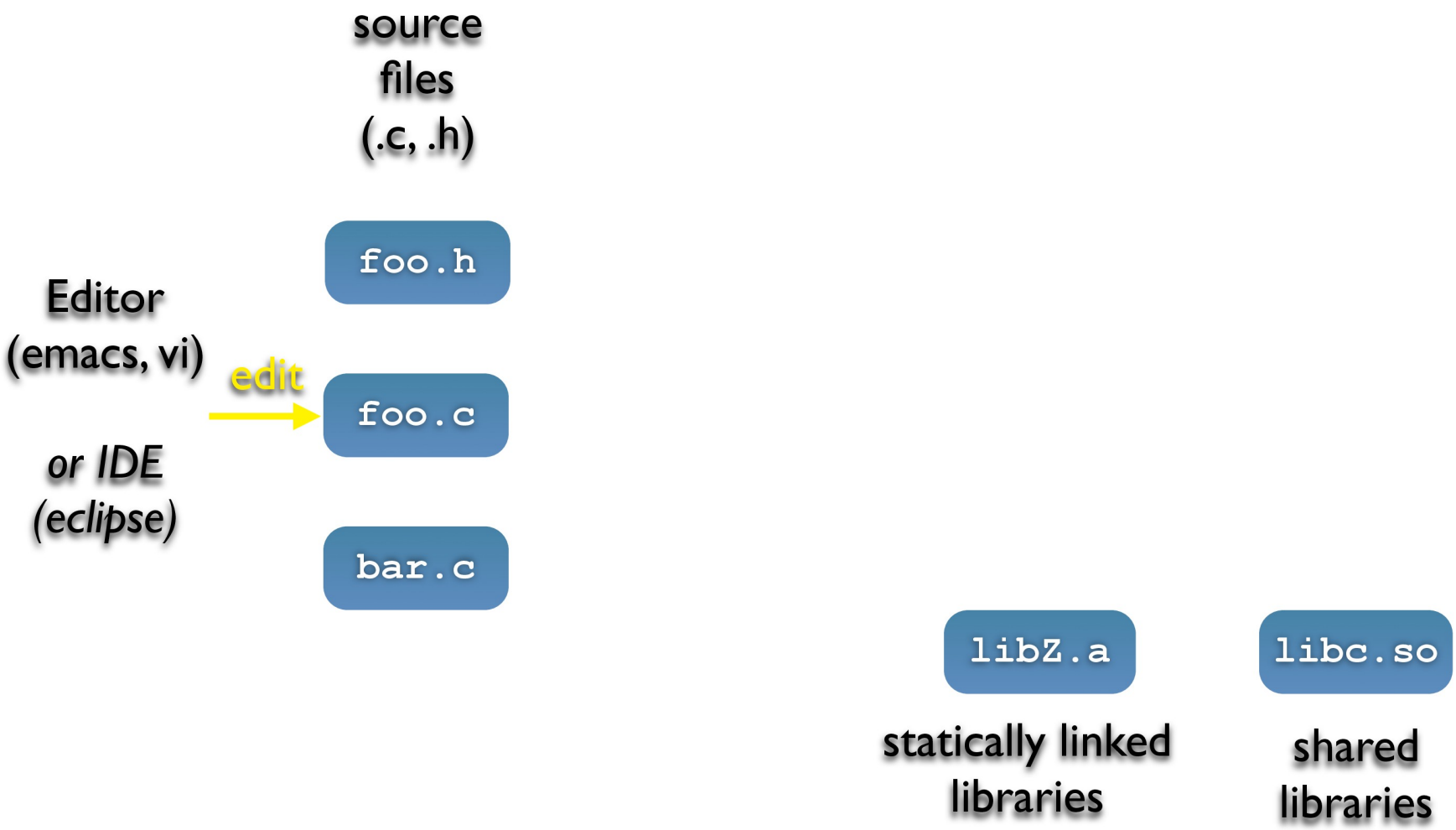
bar.c

C workflow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bar.c
libZ.a
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statically linked
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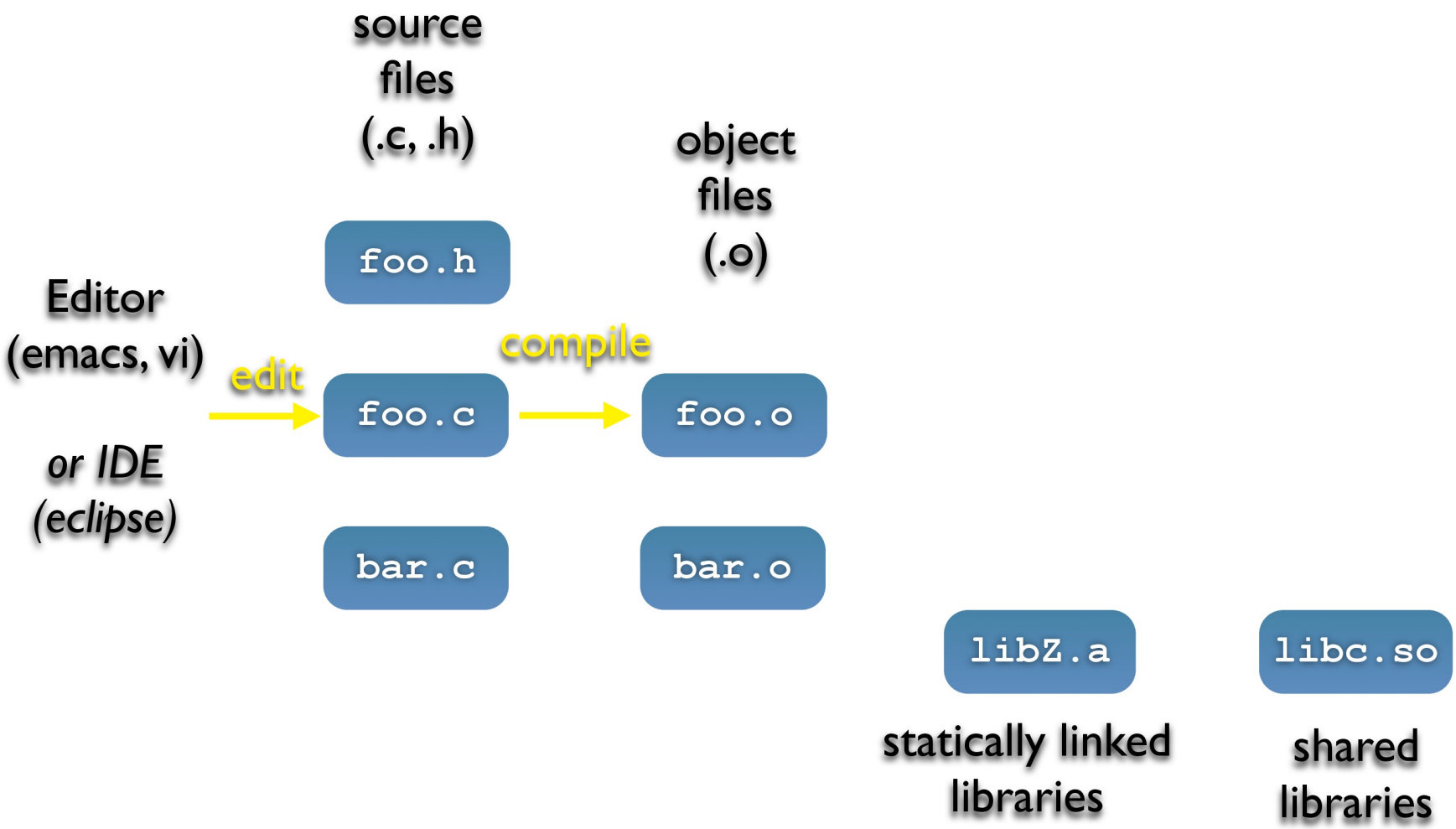
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object
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foo.h
Editor
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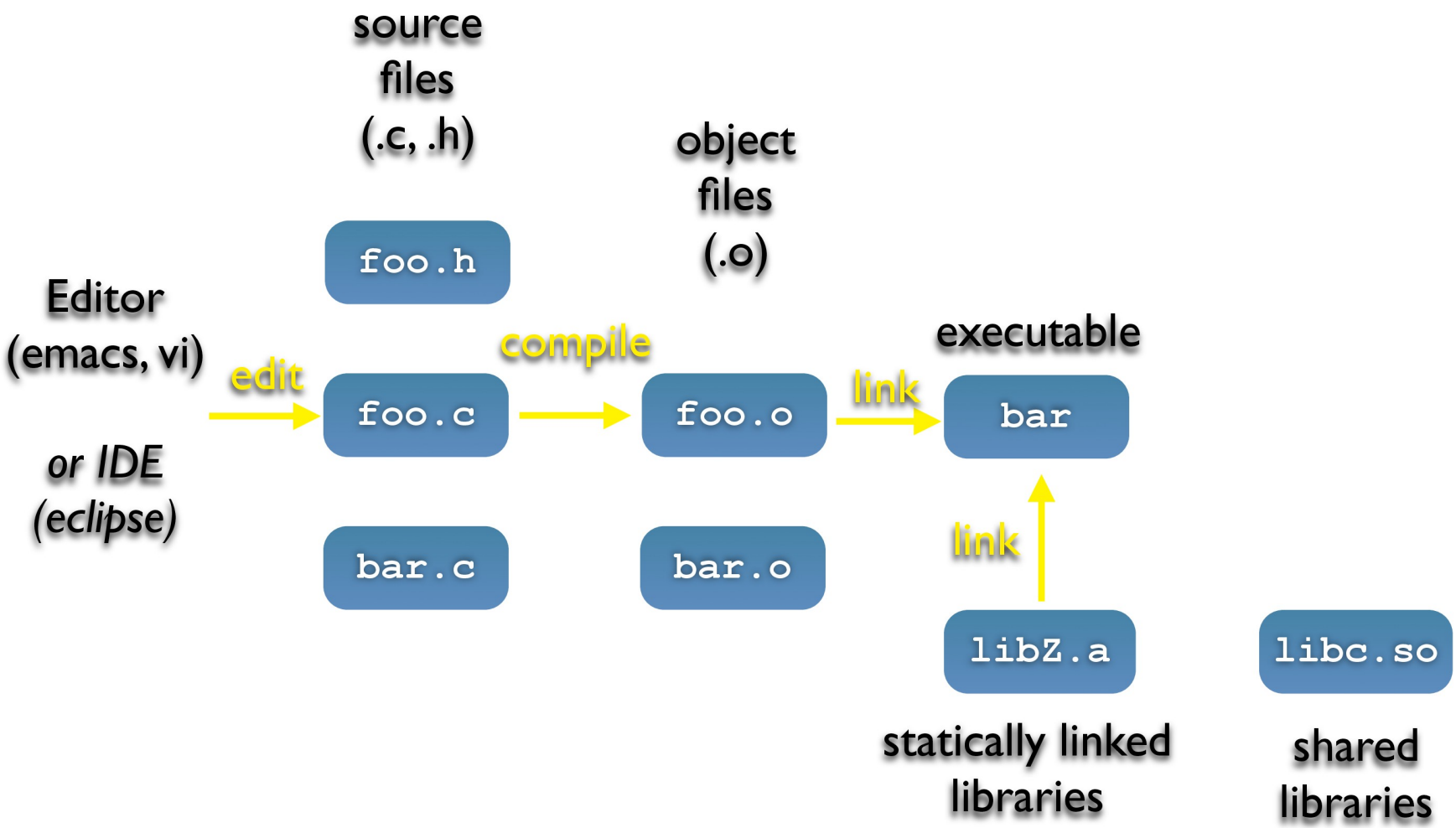
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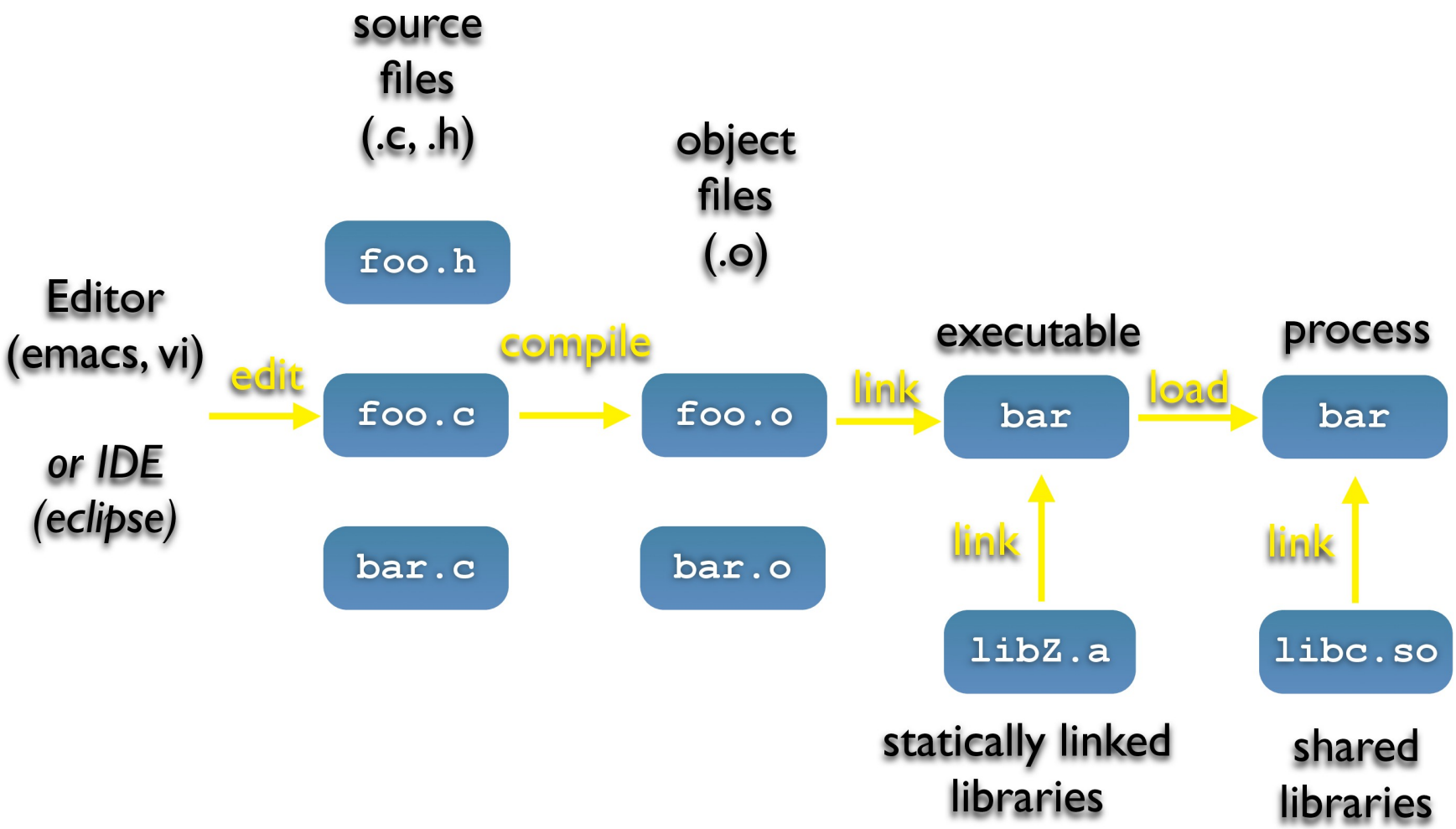
C workflow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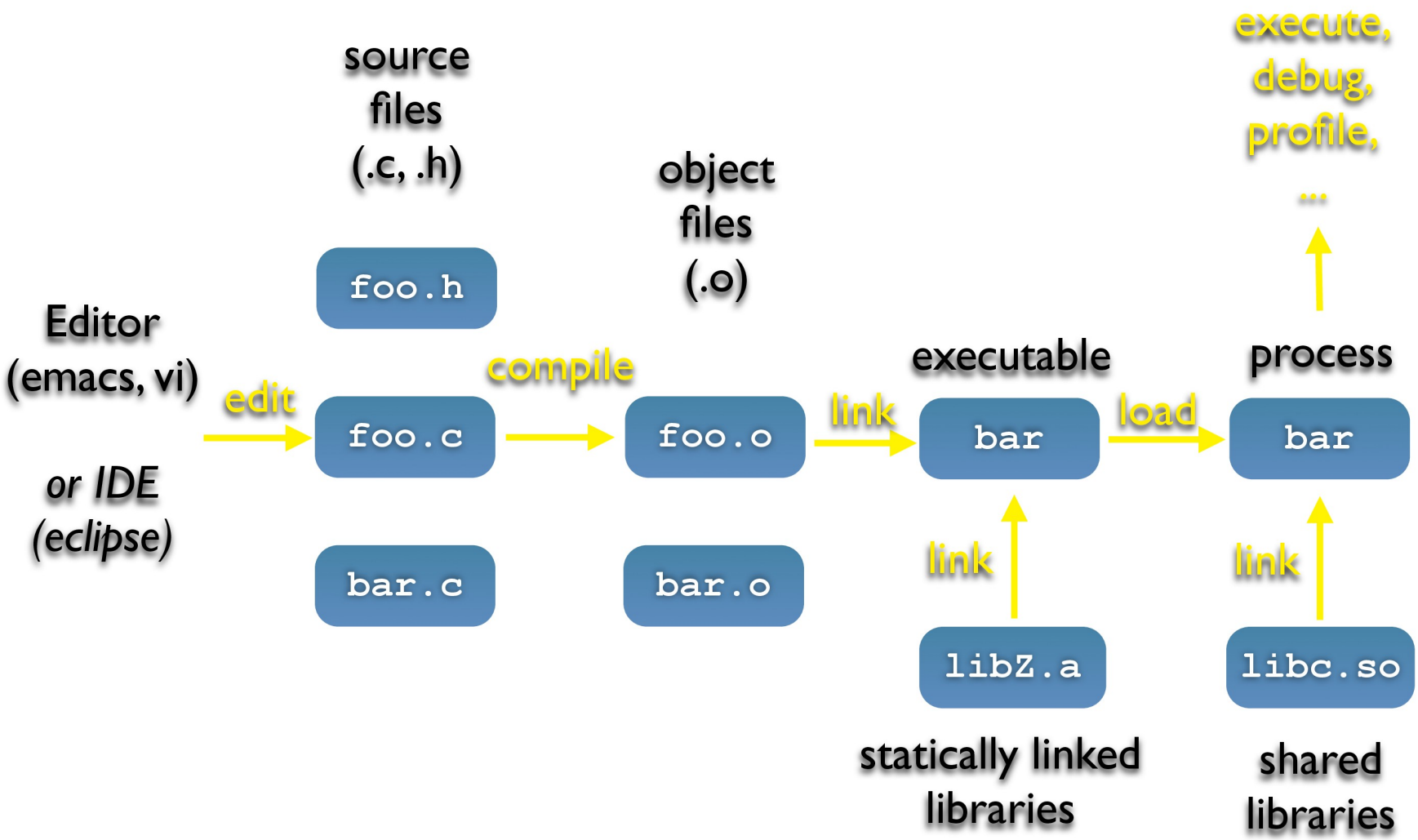
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execute,
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From C to machine code

C source file
(dosum.c)

```
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  return i+j;
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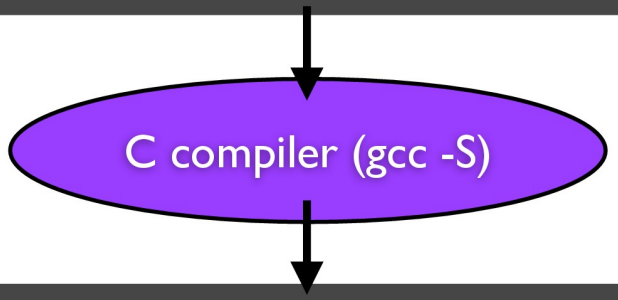
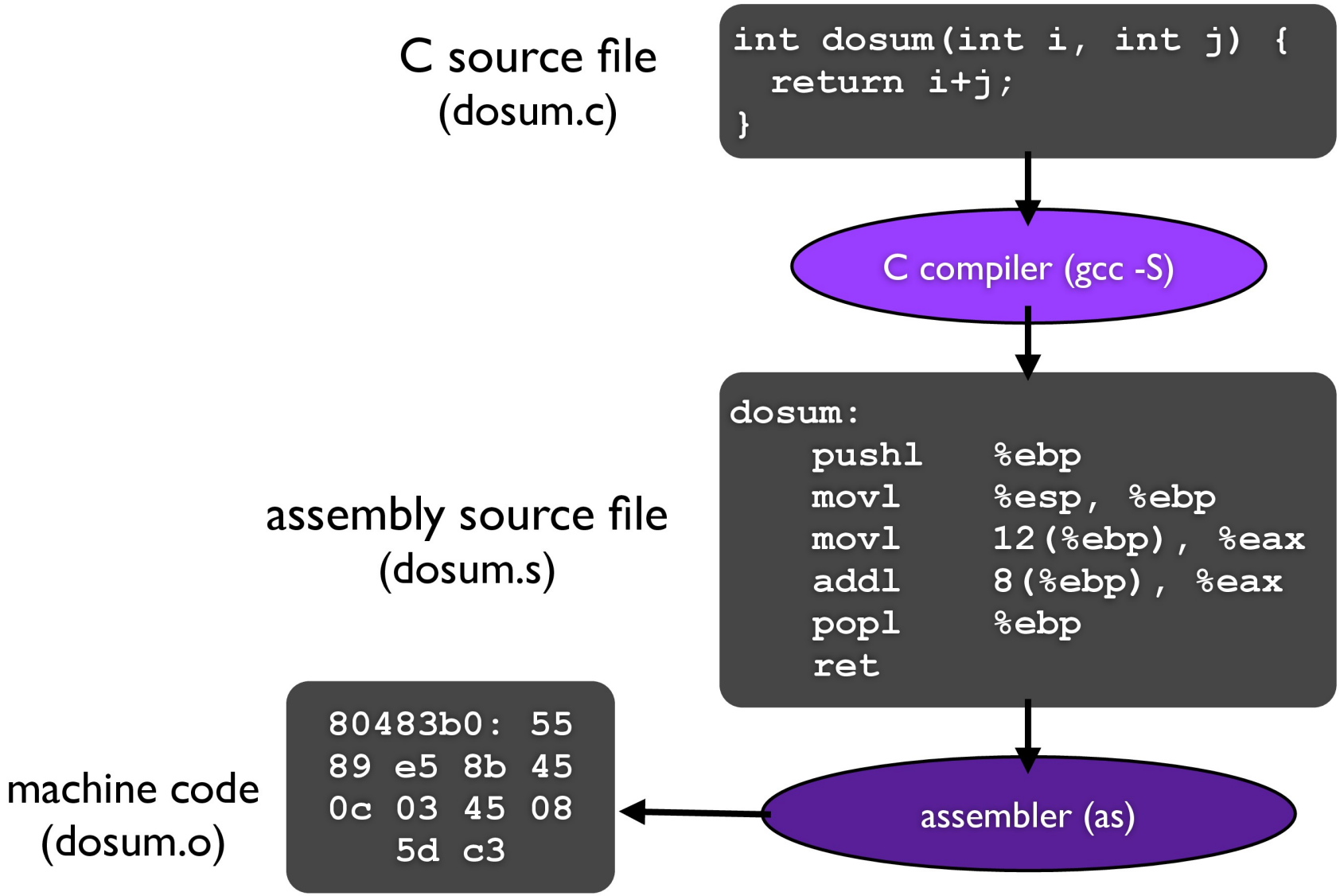


assembly source file
(dosum.s)

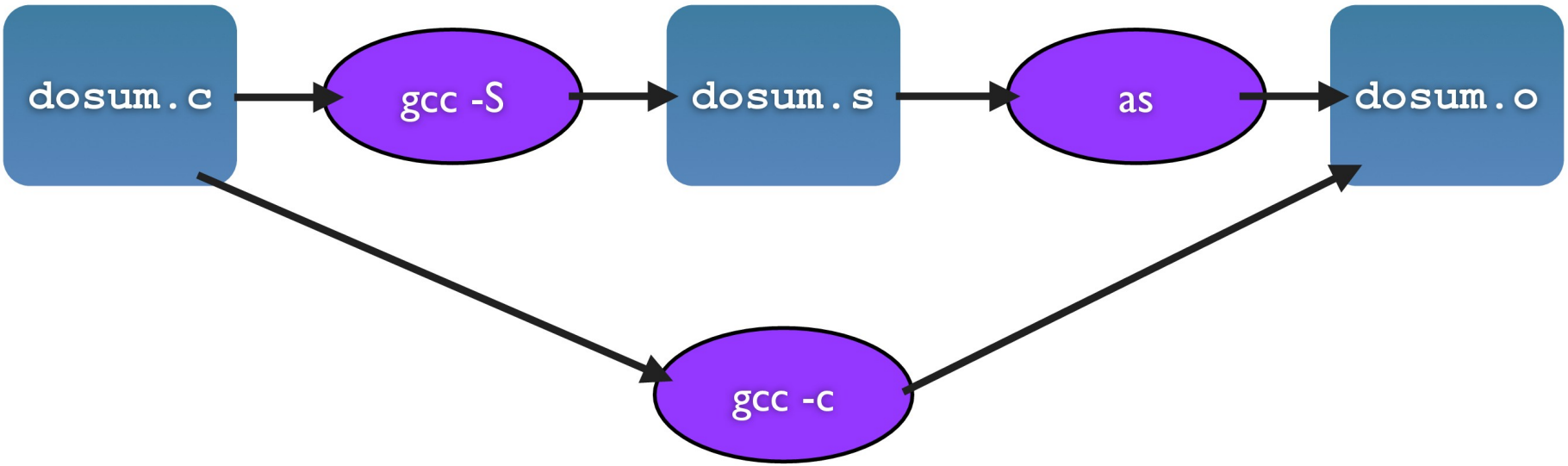
```
dosum:
    pushl   %ebp
    movl    %esp, %ebp
    movl    12(%ebp), %eax
    addl    8(%ebp), %eax
    popl    %ebp
    ret
```

From C to machine code



Skipping the ASM

- Most C compilers generate .o files (machine code) directly
  - I.e., they don't actually save the readable .s file
  - If you're curious, pass the `-S` option to `gcc`.



Multi-file C programs

C source file (dosum.c)

```
int dosum(int i, int j) {
  return i+j;
}
```

C source file (sumnum.c)

```
#include <stdio.h>

int dosum(int i, int j);

int main(int argc, char **argv) {
  printf("%d\n", dosum(1,2));
  return 0;
}
```

Multi-file C programs

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int dosum(int i, int j) {
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dosum( ) is not implemented in sumnum.c

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int dosum(int i, int j);

int main(int argc, char **argv) {
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}
```

this "prototype" of dosum( ) tells gcc about the types of dosum's arguments and its return value

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where is the implementation of printf?

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#include <stdio.h>

int dosum(int i, int j);

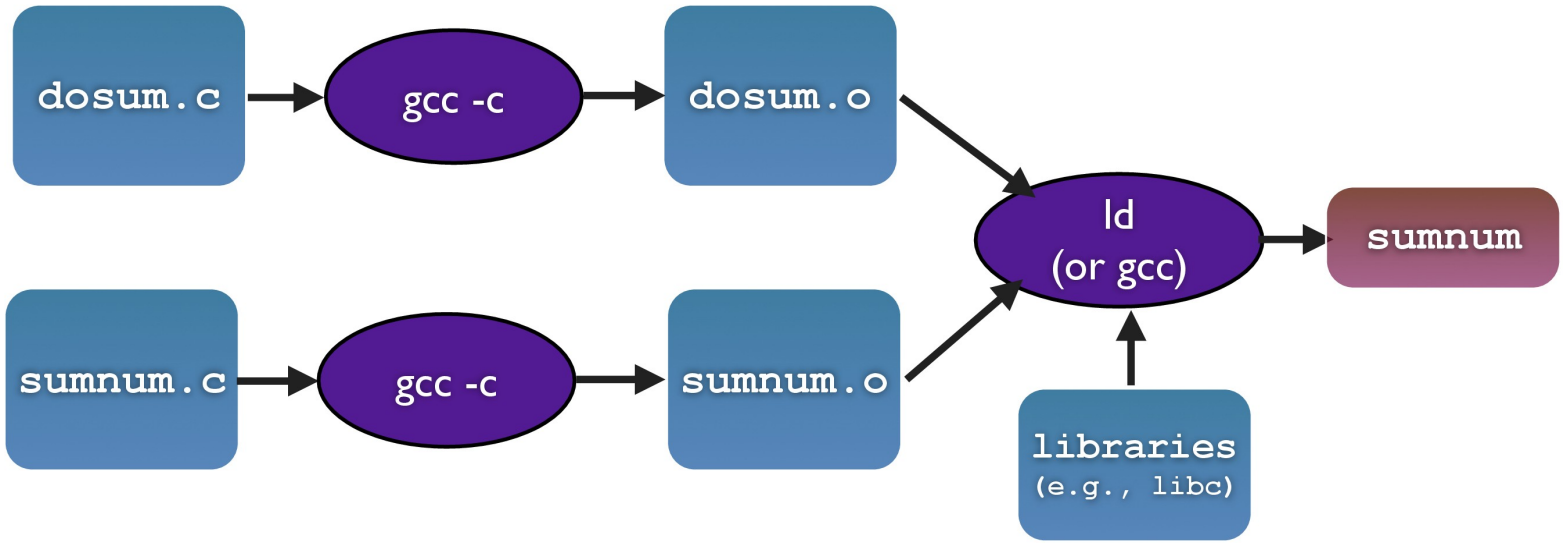
int main(int argc, char **argv) {
  printf("%d\n", dosum(1,2));
  return 0;
}
```

why do we need this #include?

where is the implementation of printf?

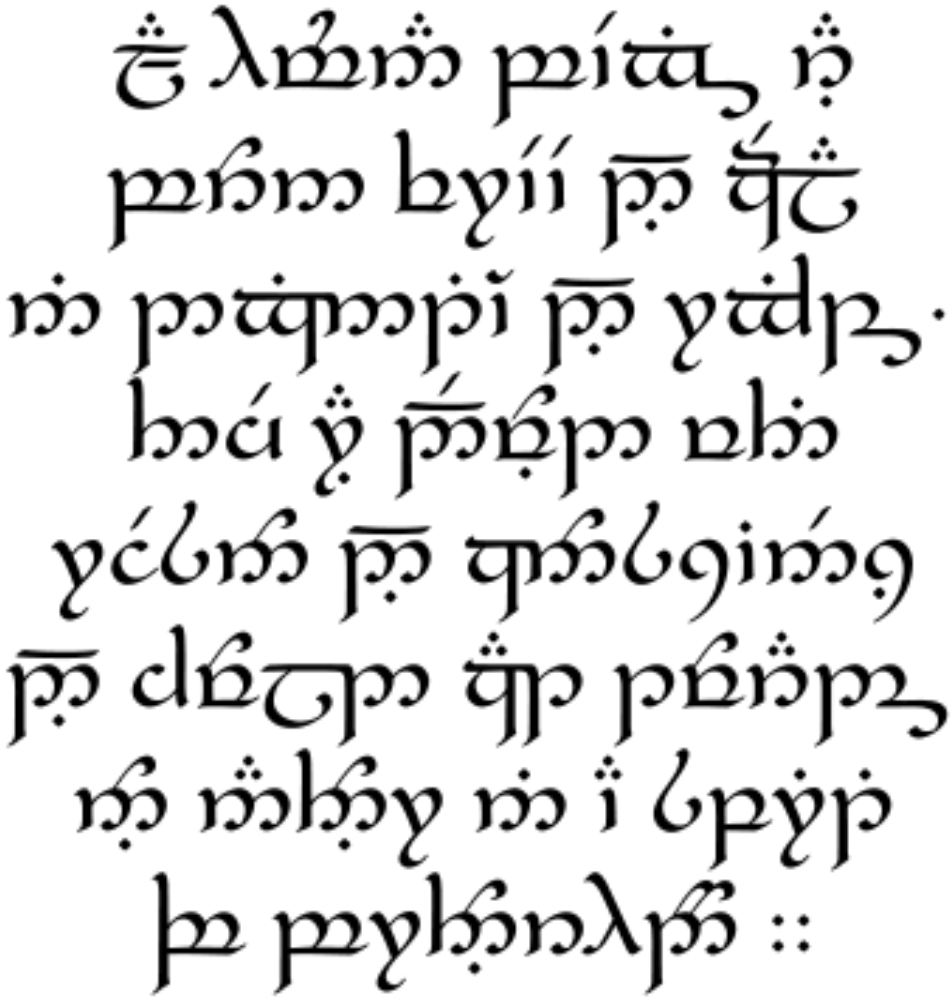
Compiling multiple files

- Multiple object files are *linked* to produce an executable
  - Standard libraries (libc, crt1, …) are usually also linked in
  - Library are just pre-assembled collections of .o files



Object files

- sumnum.o and dosum.o are *object files*
  - Each contains machine code produced by the compiler
  - Each might contain references to external symbols
    - variables and functions not defined in the associated .c file
    - e.g., the code in sumnum.o relies on printf() and dosum(), but these are defined in libc.a and dosum.o, respectively
  - Linking combines the needed object files and libraries to resolve these external symbols



The C language

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- Things that are the same as Java and C++:
  - Syntax of statements, control structures, function calls
  - Primitive types: `int`, `double`, `char`, `long`, `float`
  - Type-casting syntax: `double x = (double) 5 / 3;`
  - Expressions, operators, precedence
    - `! ++ -- * / % + - < <= > >= == != && || = += -= *= /= %=`
  - Static scope: local scope within `{curly braces}`
  - Comments: `/* comment */` or `// comment`

Primitive types in C

- Integer types
  - char, int
- Floating point types
  - float, double
- Modifiers
  - short [int]
  - long [int, double]
  - long long [int]
  - signed [char, int]
  - unsigned [char, int]

type	bytes (32 bit)	bytes (64 bit)	32 bit range	printf
char	1	1	[0, 255]	%c
short int	2	2	[-32768,32767]	%hd
unsigned short int	2	2	[0, 65535]	%hu
int	4	4	[-214748648, 2147483647]	%d
unsigned int	4	4	[0, 4294967295]	%u
long int	4	8	[-2147483648, 2147483647]	%ld
long long int	8	8	[-9223372036854775808, 9223372036854775807]	%lld
float	4	4	approx [10^{-38}, 10^{38}]	%f
double	8	8	approx [10^{-308}, 10^{308}]	%lf
long double	12	16	approx [10^{-4932}, 10^{4932}]	%Lf
pointer	4	8	[0, 4294967295]	%p

C99 fixed-width int types

- What type can I use to get exactly 32 bits?

```
#include <stdint.h>

void foo(void) {
  int8_t  w;     // exactly 8 bits, signed
  int16_t x;     // exactly 16 bits, signed
  int32_t y;     // exactly 32 bits, signed
  int64_t z;     // exactly 64 bits, signed

  uint8_t w;     // exactly 8 bits, unsigned
  ...etc.
}
```

Similar to Java/C++

- Variables
  - Declared at the start of a function or block (changed in C99)
  - Need not be initialized before use (`gcc -Wall` will warn)

```c
#include <stdio.h>

int main(int argc, char **argv) {
  int x, y = 5;   // note x is uninitialized!
  long z = x+y;

  printf("z is '%ld'\n", z); // what's printed?
  {
    int y = 10;
    printf("y is '%d'\n", y);
  }
  int w = 20;  // ok in c99
  printf("y is '%d', w is '%d'\n", y, w);
  return 0;
}
```

Similar to Java/C++

- `const`
  - Qualifier that indicates the variable's value cannot change
  - Compiler will issue an **error** if you try to violate this
- Why is this qualifier useful?

```c
#include <stdio.h>

int main(int argc, char **argv) {
  const double MAX_GPA = 4.0;

  printf("MAX_GPA: %g\n", MAX_GPA);
  MAX_GPA = 5.0;  // illegal!
  return 0;
}
```

Similar to Java/C++

- `for` loops
  - Can't declare variables in the loop header (changed in C99)
- `if`/`else`, `while`, and `do`/`while` loops
  - No boolean type (changed in C99)
  - Any type can be used: 0 and NULL are false, everything else true

```
int i;

for (i=0; i<100; i++) {
  if (i % 10 == 0) {
    printf("i: %d\n", i);
  }
}
```

Similar to Java/C++

- C always passes arguments by value
  - Value is *copied* into function
  - Any local change is not reflected in the original value that was passed
- Pointers let you pass by reference
  - Copy the memory location of the variable and use that to change the original
  - Most tricky and dangerous feature of C!

```
void add_pbv(int c) {
  c += 10;
  printf("pbv c: %d\n", c);
}

void add_pbr(int *c) {
  *c += 10;
  printf("pbr *c: %d\n", *c);
}

int main(int argc, char **argv) {
  int x = 1;

  printf("x: %d\n", x);

  add_pbv(x);
  printf("x: %d\n", x);

  add_pbr(&x);
  printf("x: %d\n", x);

  return 0;
}
```

Pass-by-value

- Passing arguments by value
  - Callee receives its own copy of the argument
  - If the callee modifies its copy, the caller's copy isn't modified

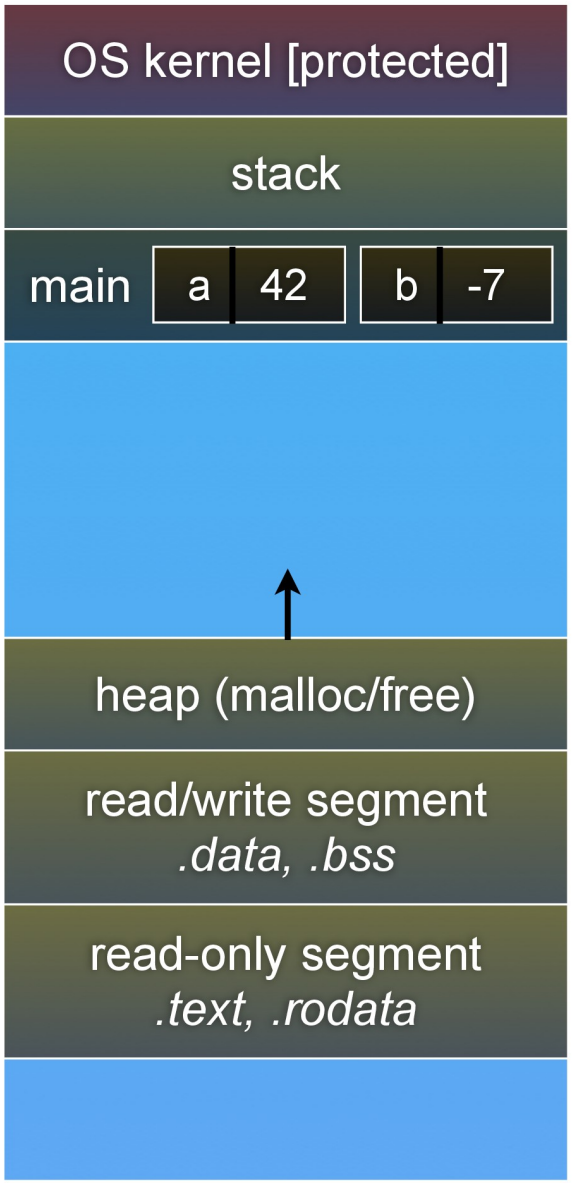
```
void swap(int a, int b) {
  int tmp = a;
  a = b;
  b = tmp;
}

int main(int argc, char **argv) {
  int a = 42, b = -7;

  swap(a, b);
  printf("a: %d, b: %d\n", a, b);
  return 0;
}
```

^ Does not work!

Pass-by-value

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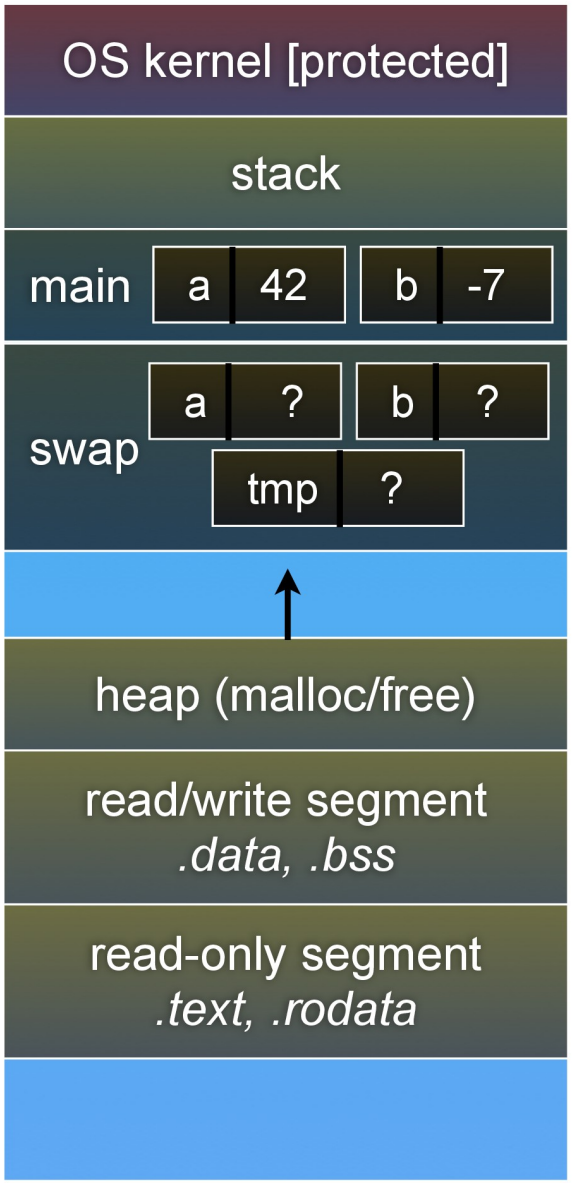


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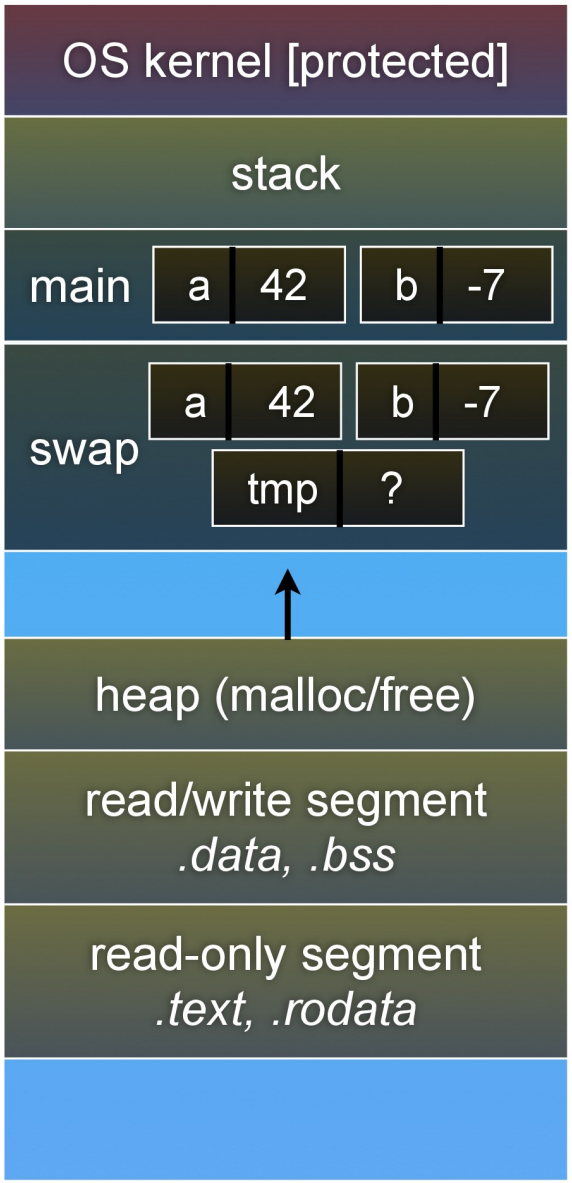


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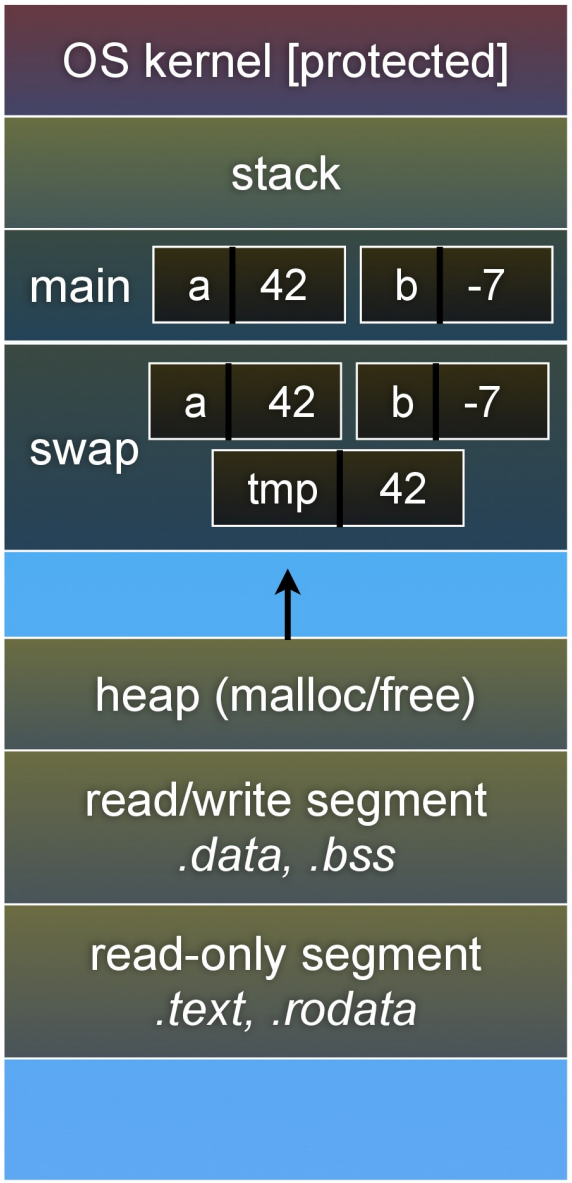


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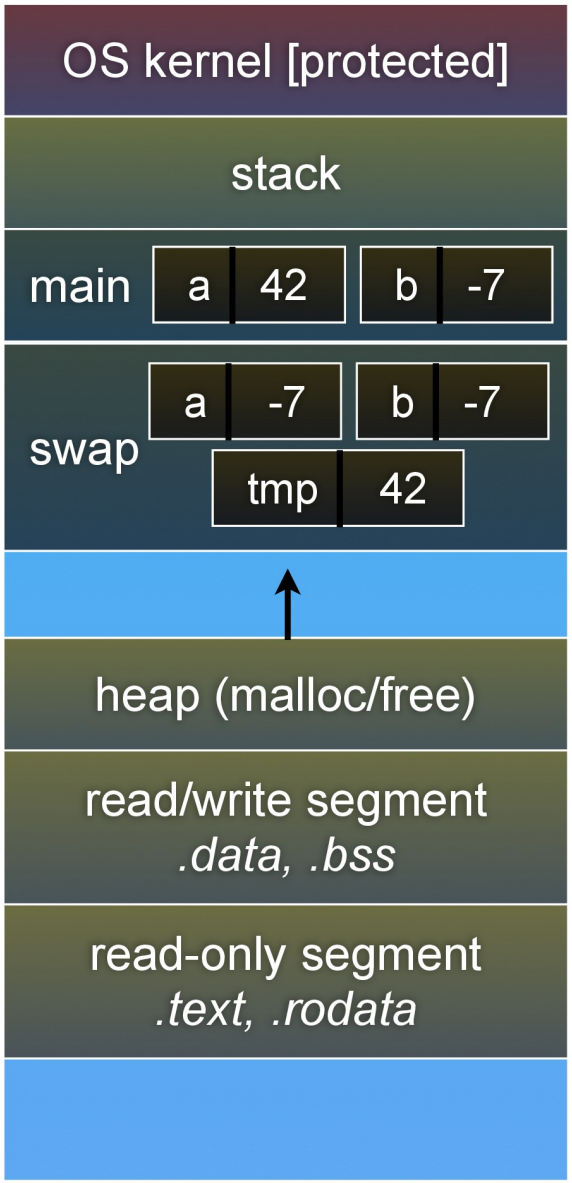


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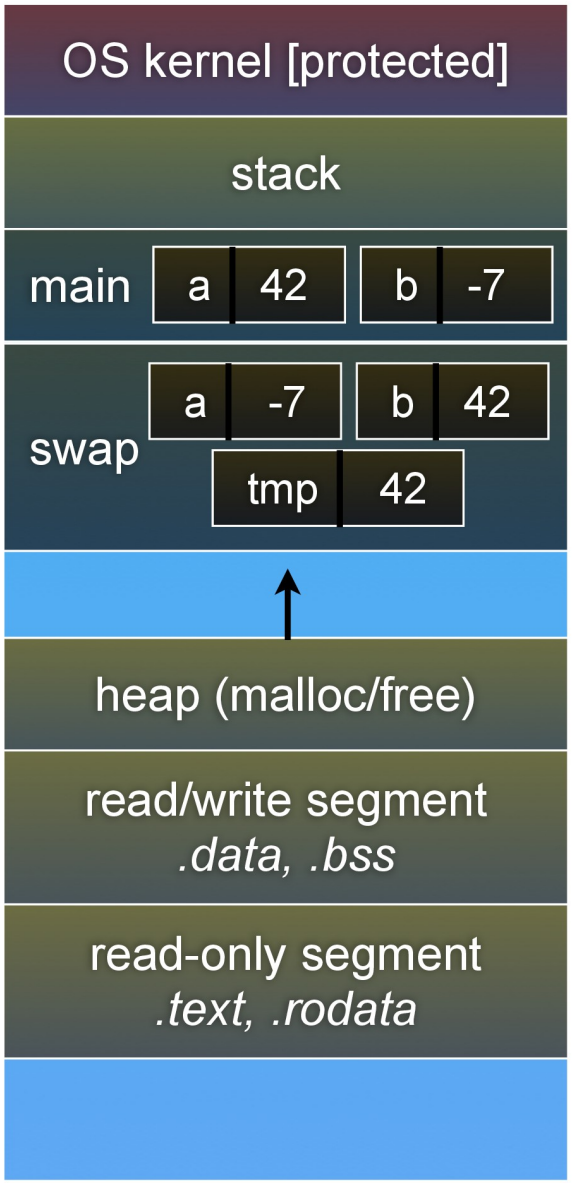


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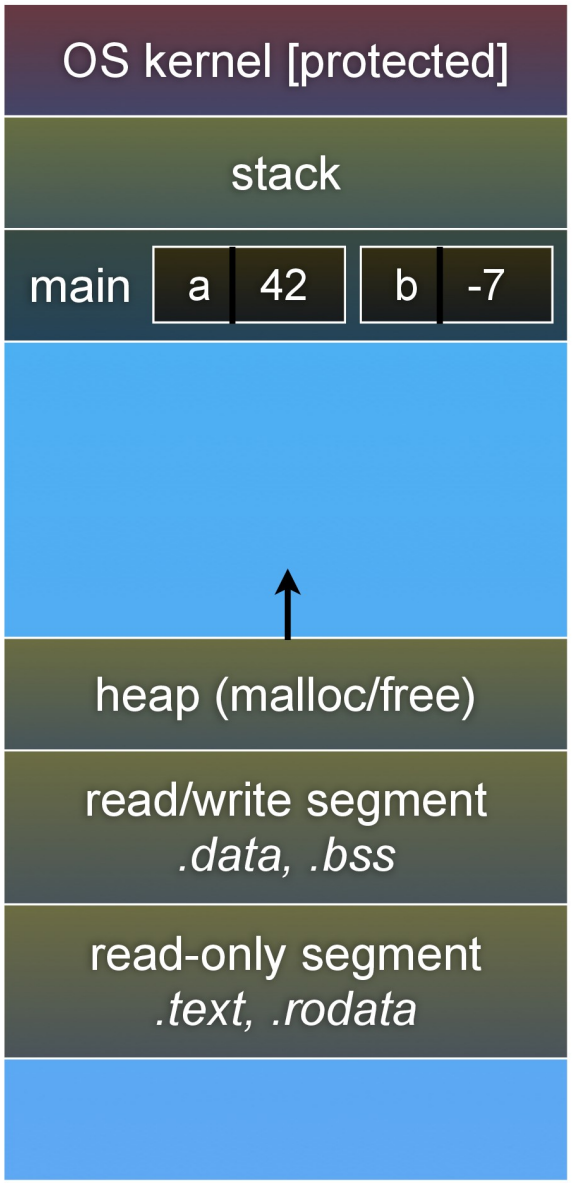


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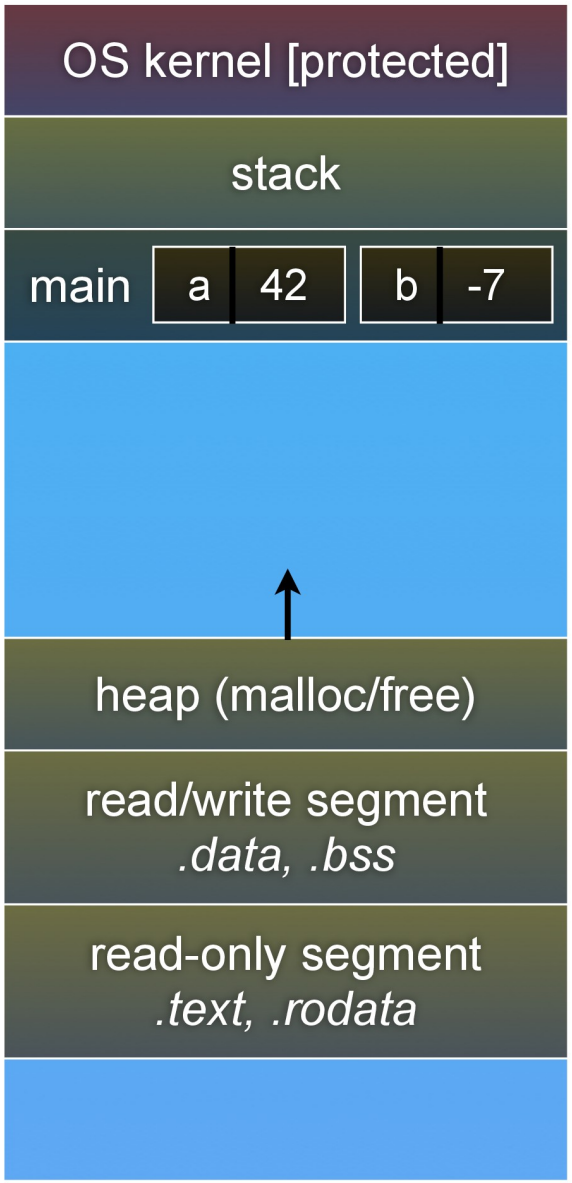


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  b = tmp;
}

int main(int argc, char **argv) {
  int a = 42, b = -7;

  swap(a, b);
  printf("a: %d, b: %d\n", a, b);
  return 0;
}
```

^ Does not work!

Pass-by-reference

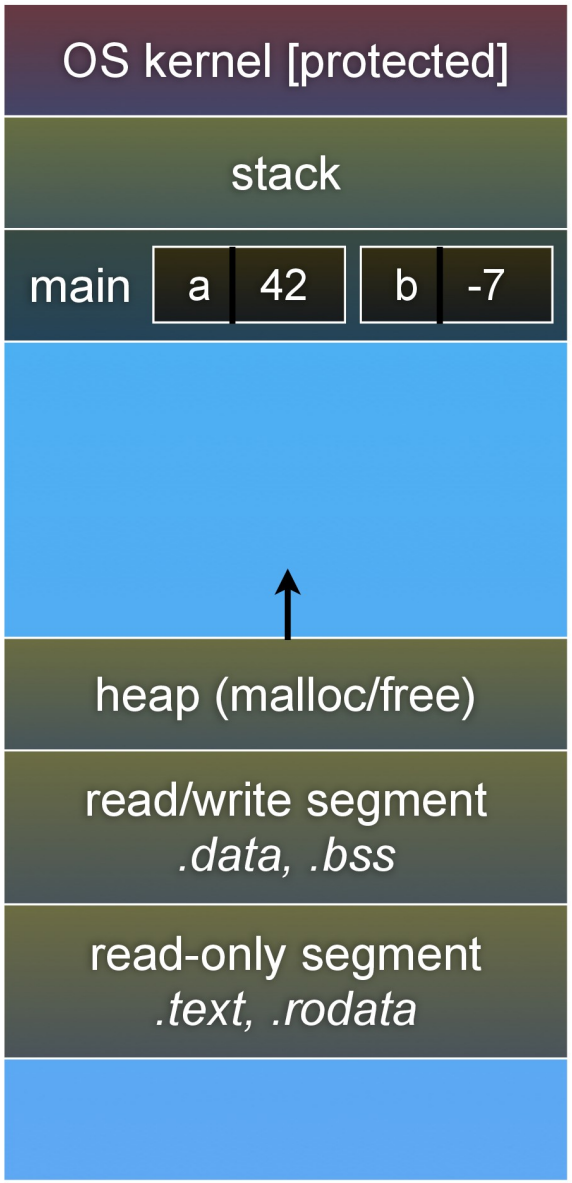
- You can use pointers to pass by reference
  - callee still receives a copy of the argument
    - but the argument is a pointer
    - the pointer's value is an address that points to the variable
  - This gives the callee a way to modify a variable that's in the caller's scope.

```
void swap(int *a, int *b) {
  int tmp = *a;
  *a = *b;
  *b = tmp;
}

int main(int argc, char **argv) {
  int a = 42, b = -7;

  swap(&a, &b);
  printf("a: %d, b: %d\n", a, b);
  return 0;
}
```

Pass-by-reference

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```
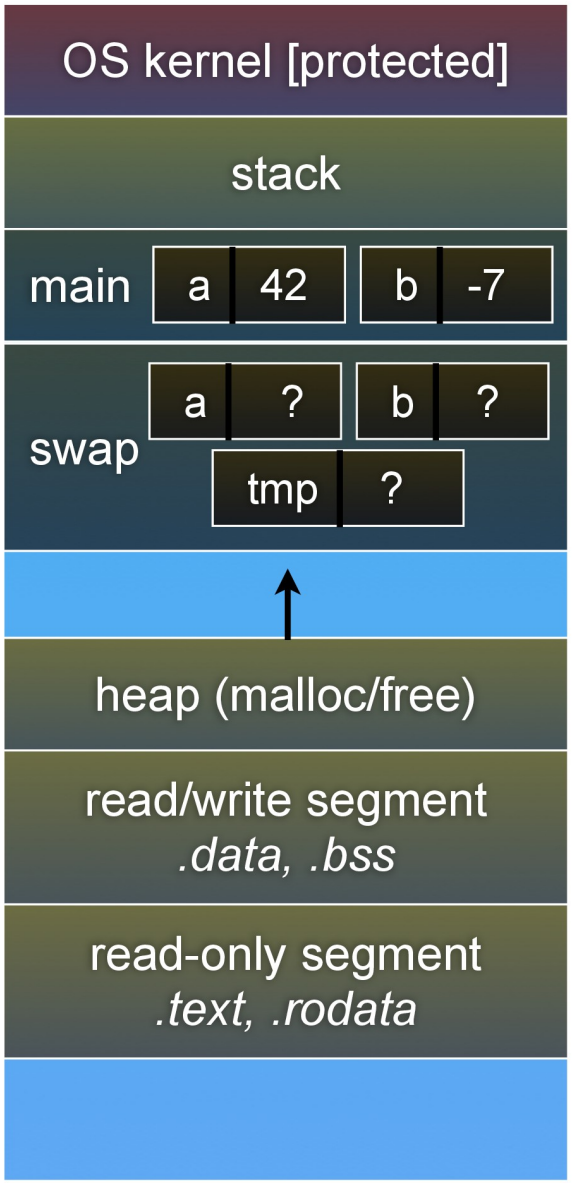

Pass-by-reference

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void swap(int *a, int *b) {
  int tmp = *a;
  *a = *b;
  *b = tmp;
}

int main(int argc, char **argv) {
  int a = 42, b = -7;

  swap(&a, &b);
  printf("a: %d, b: %d\n", a, b);
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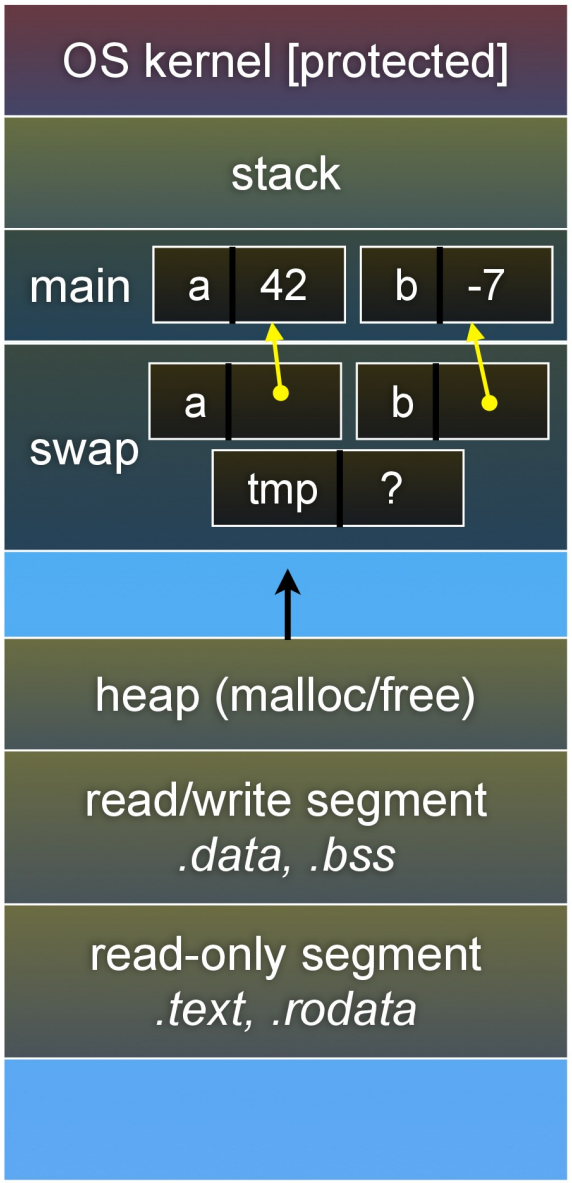
Pass-by-reference

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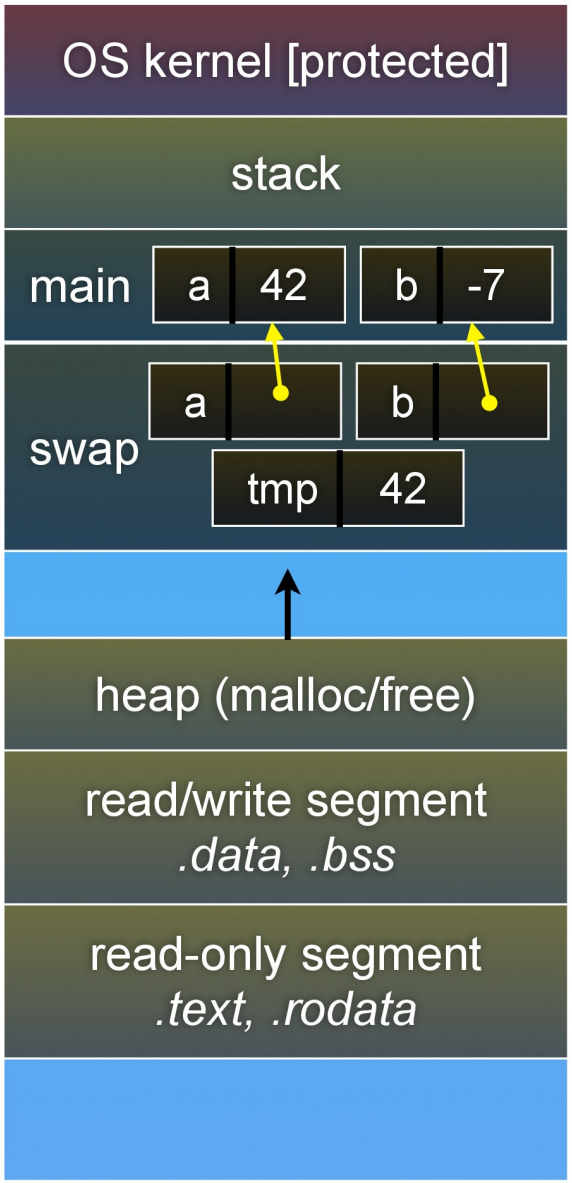


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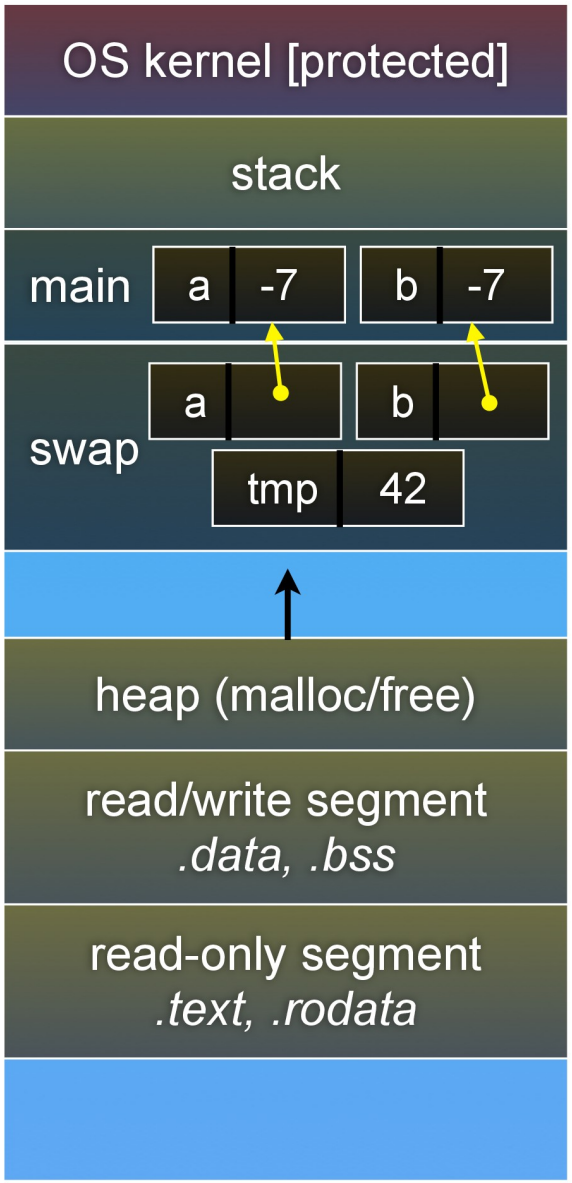


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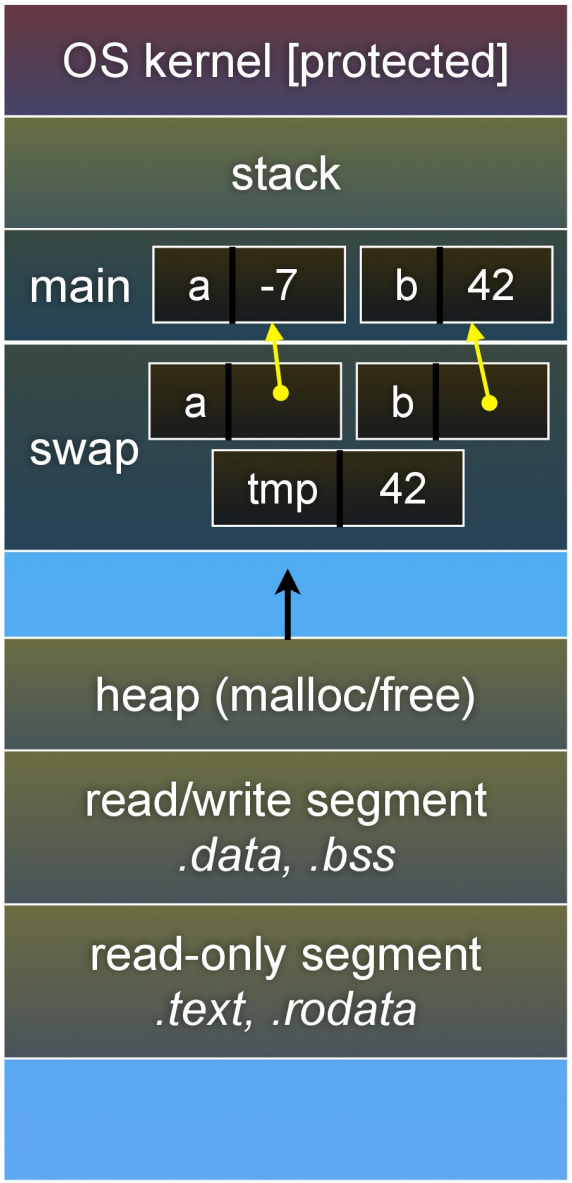


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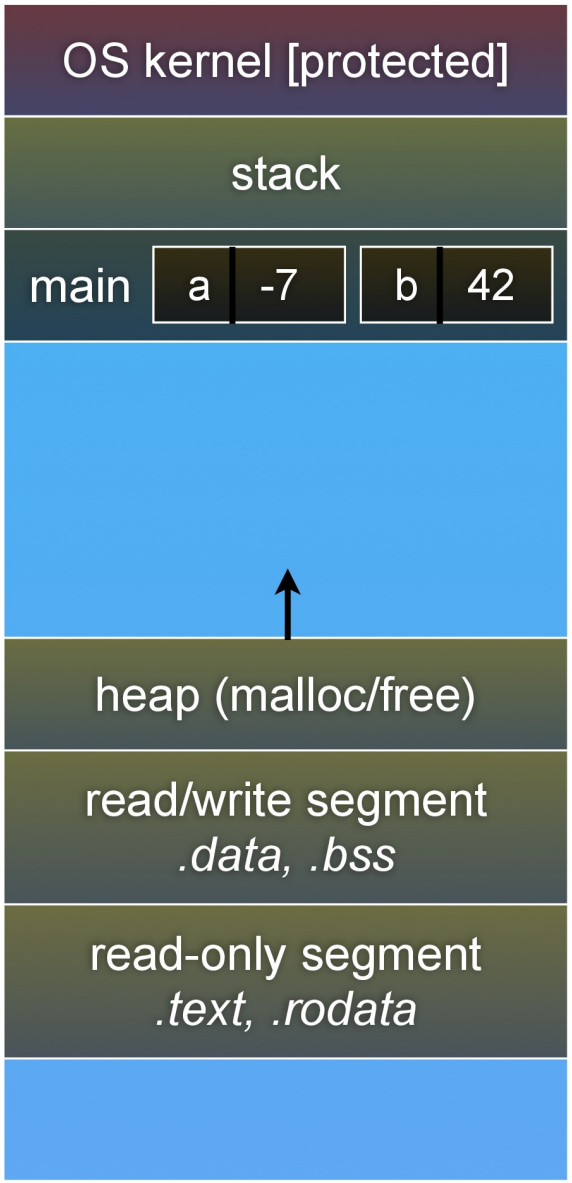


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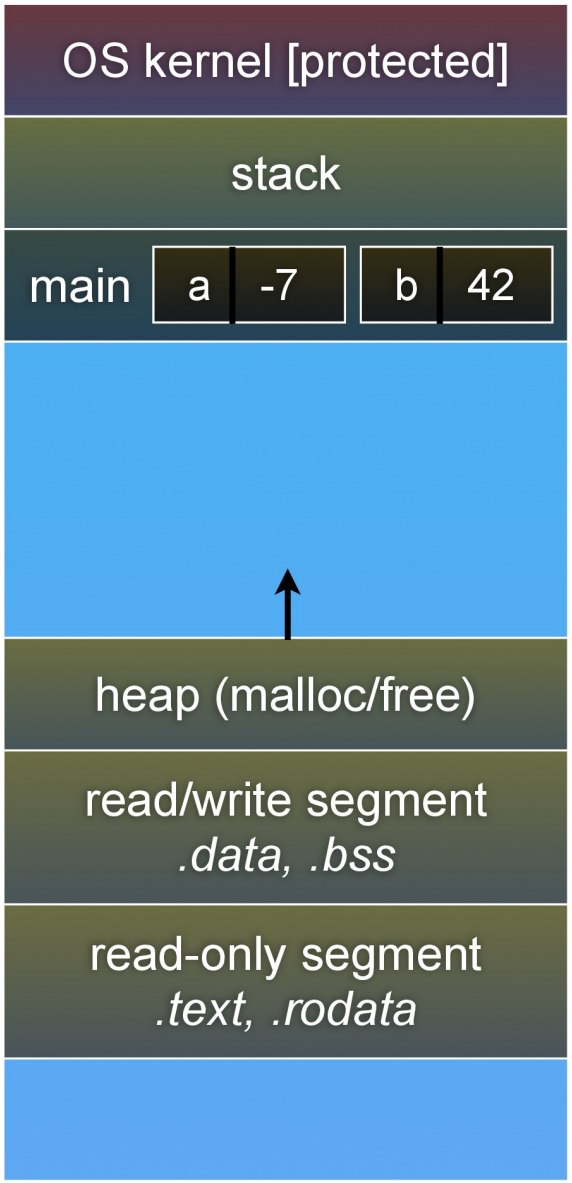


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