Introduction to 8086 Assembly

Lecture 11

Modular Programming
in C and Assembly

Modular Programming

test.c

```c
#include <stdio.h>

extern int fact(int);

extern int maxval;

int main() {
  int x = 8;
  printf("mv=%d\n", maxval);
  printf("x!=%d\n", fact(x));

  return  0;
}
```

fact.c

```c
int maxval = 2;
static int flag = 1;

int fact(int n) {
  return n==0 ? 1 : n*fact(n-1);
}

static int condmax(int a, int b) {
  return (a > b && flag) ? a : b;
}
```

Modular Programming

test.c

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extern int maxval;

int main() {
  int x = 8;
  printf("mv=%d\n", maxval);
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static int condmax(int a, int b) {
  return (a > b && flag) ? a : b;
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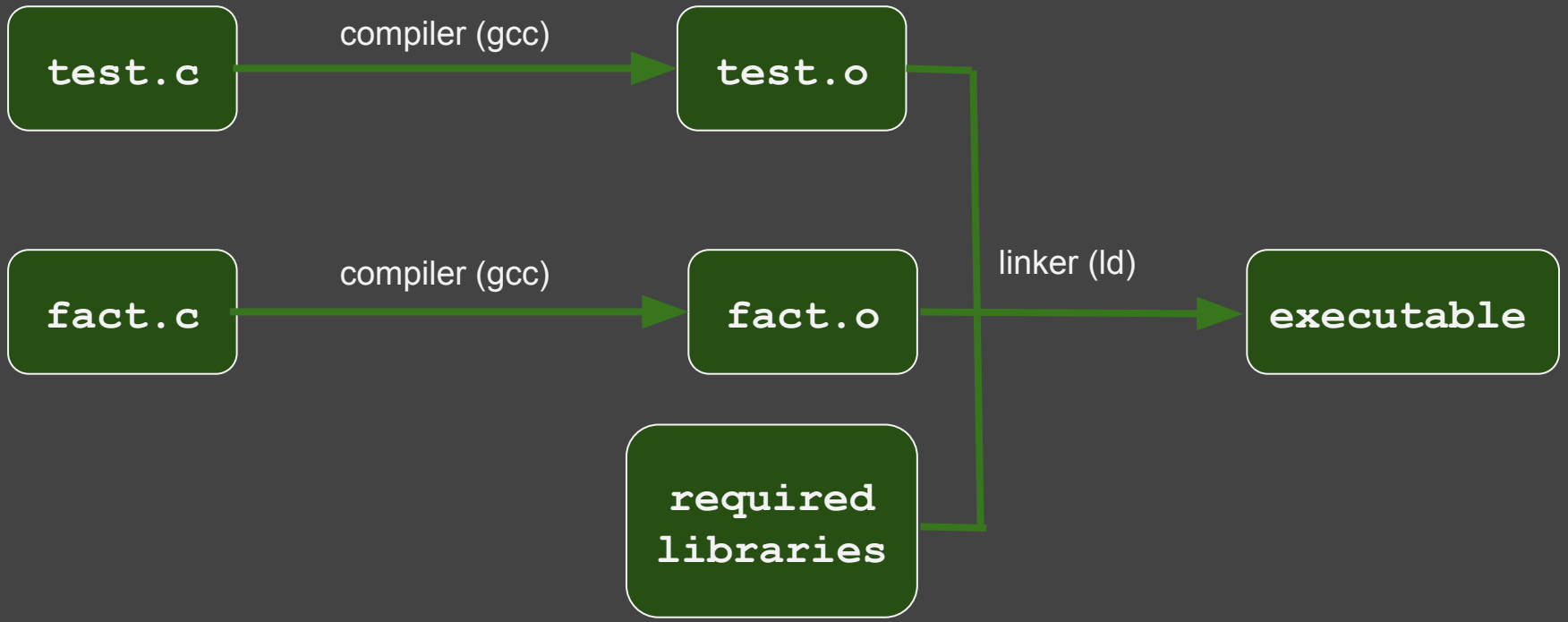
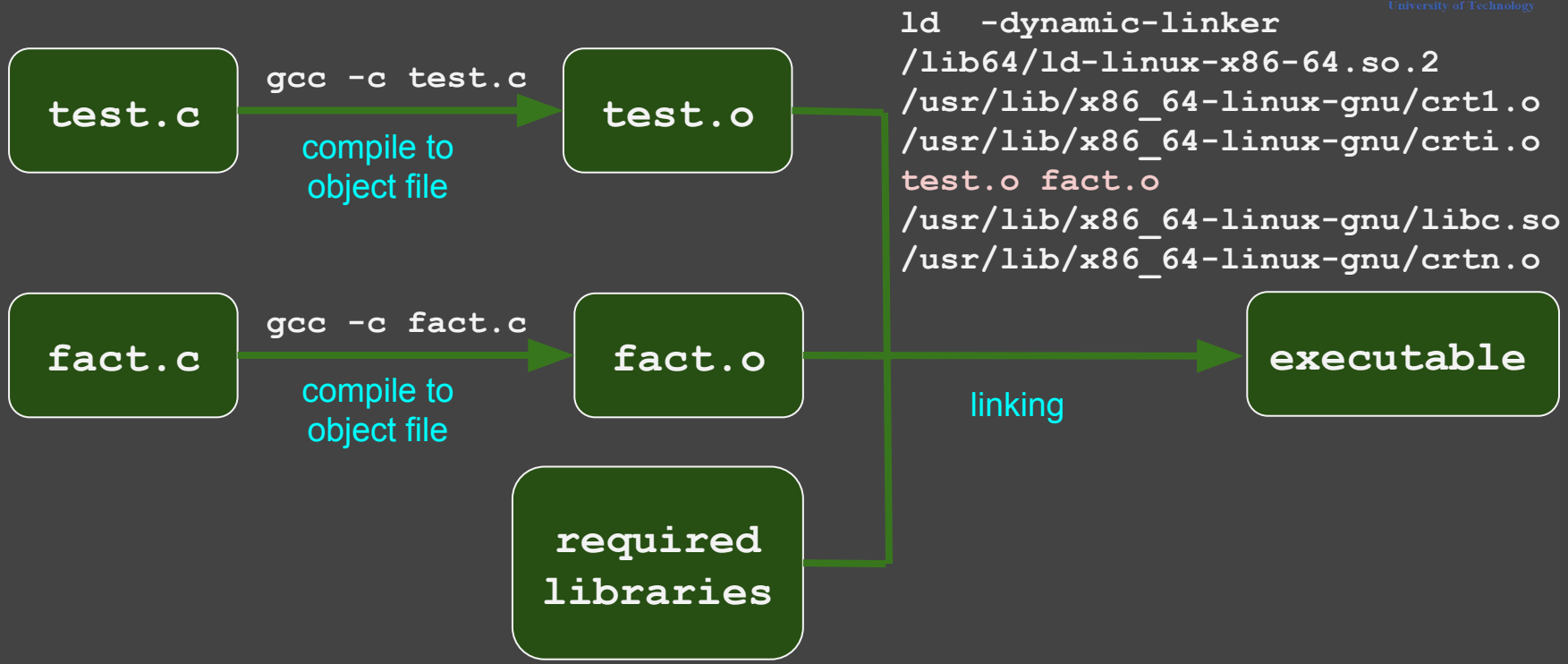
```

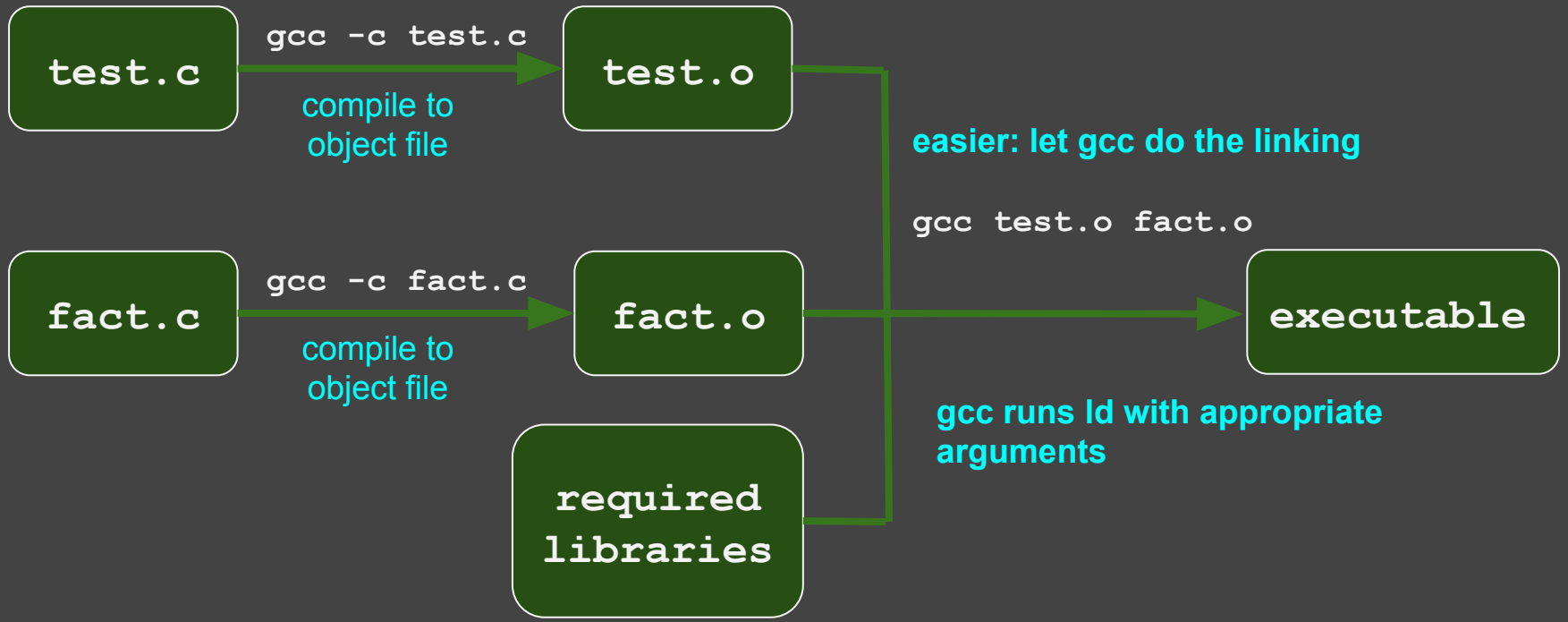
Remember: Compiling and linking C files



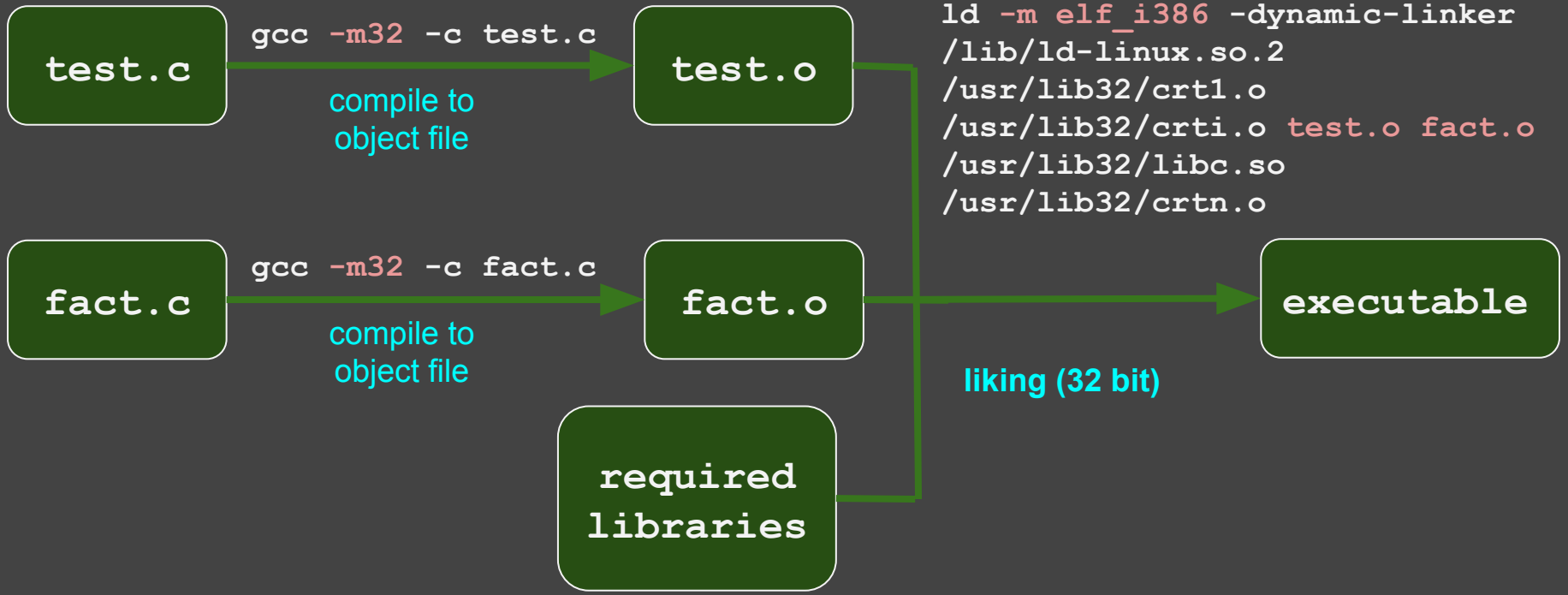
Remember: Compiling and linking C files



Remember: Compiling and linking C files



32 bit Compiling and linking C files



32 bit Compiling and linking C files

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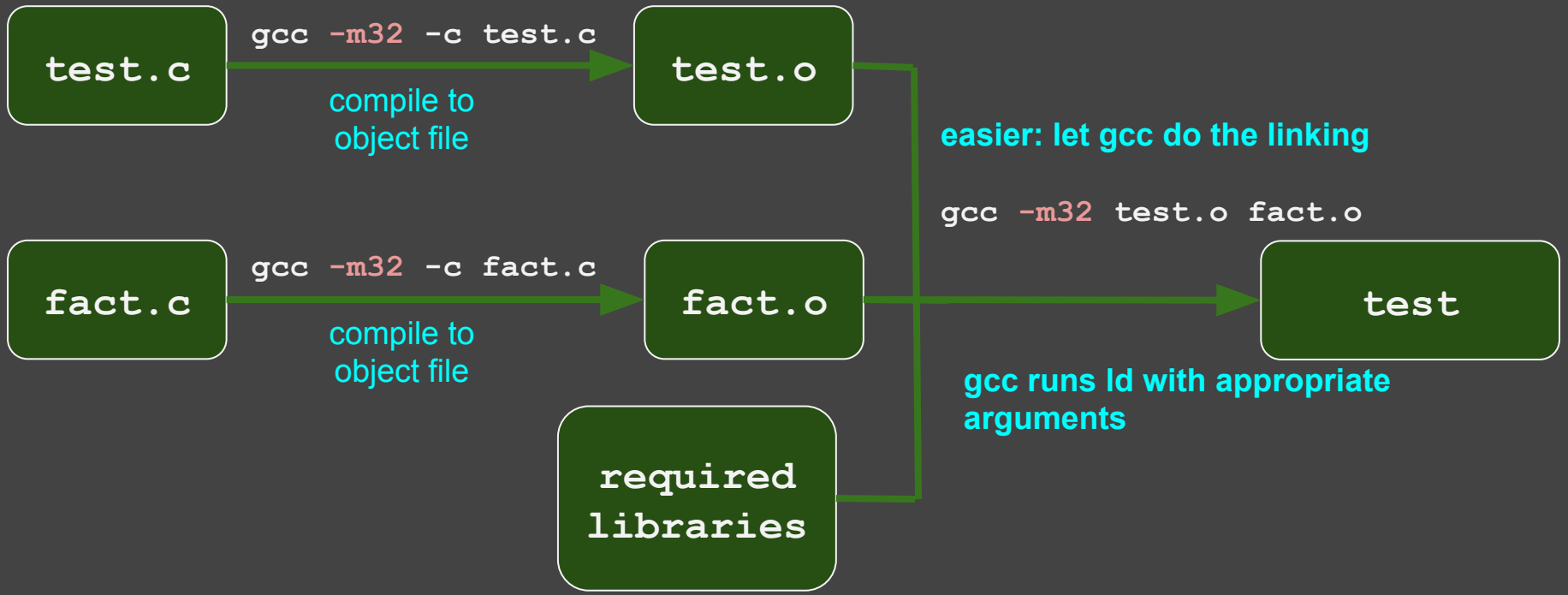
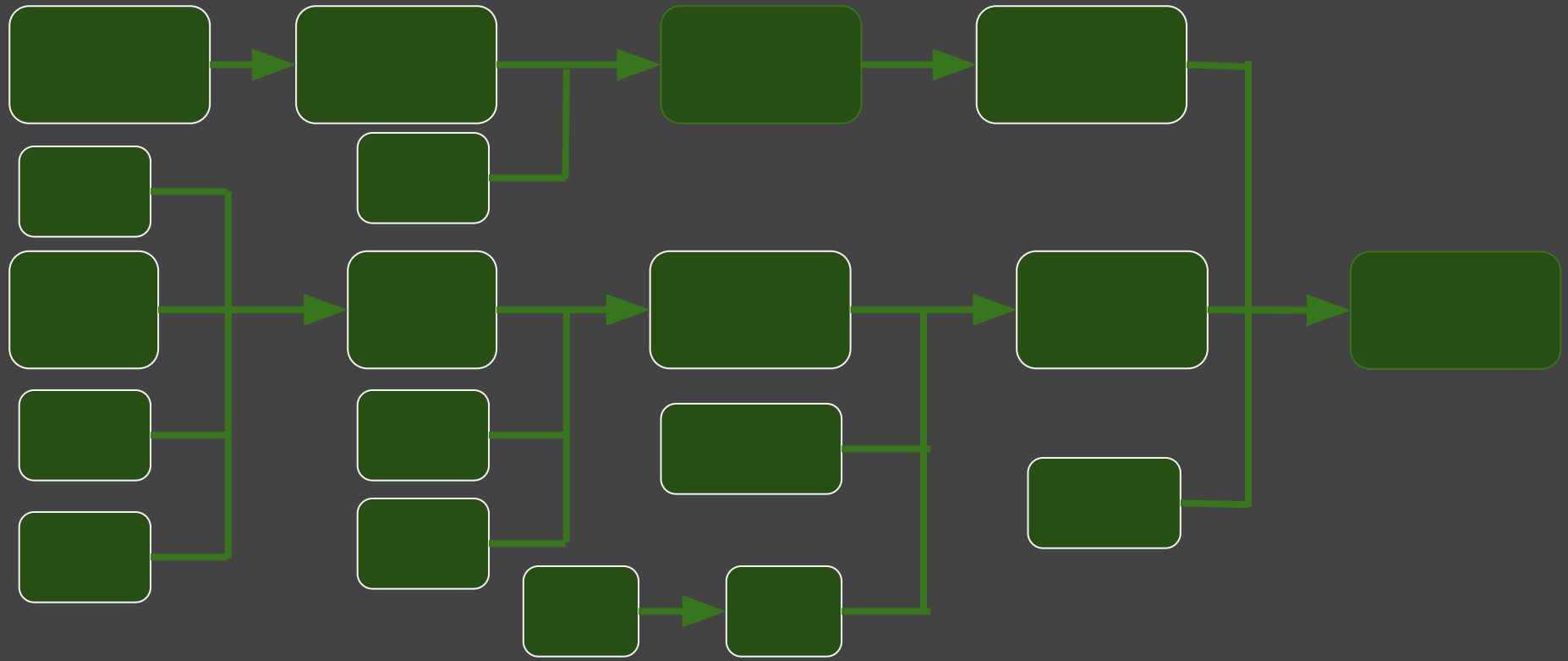
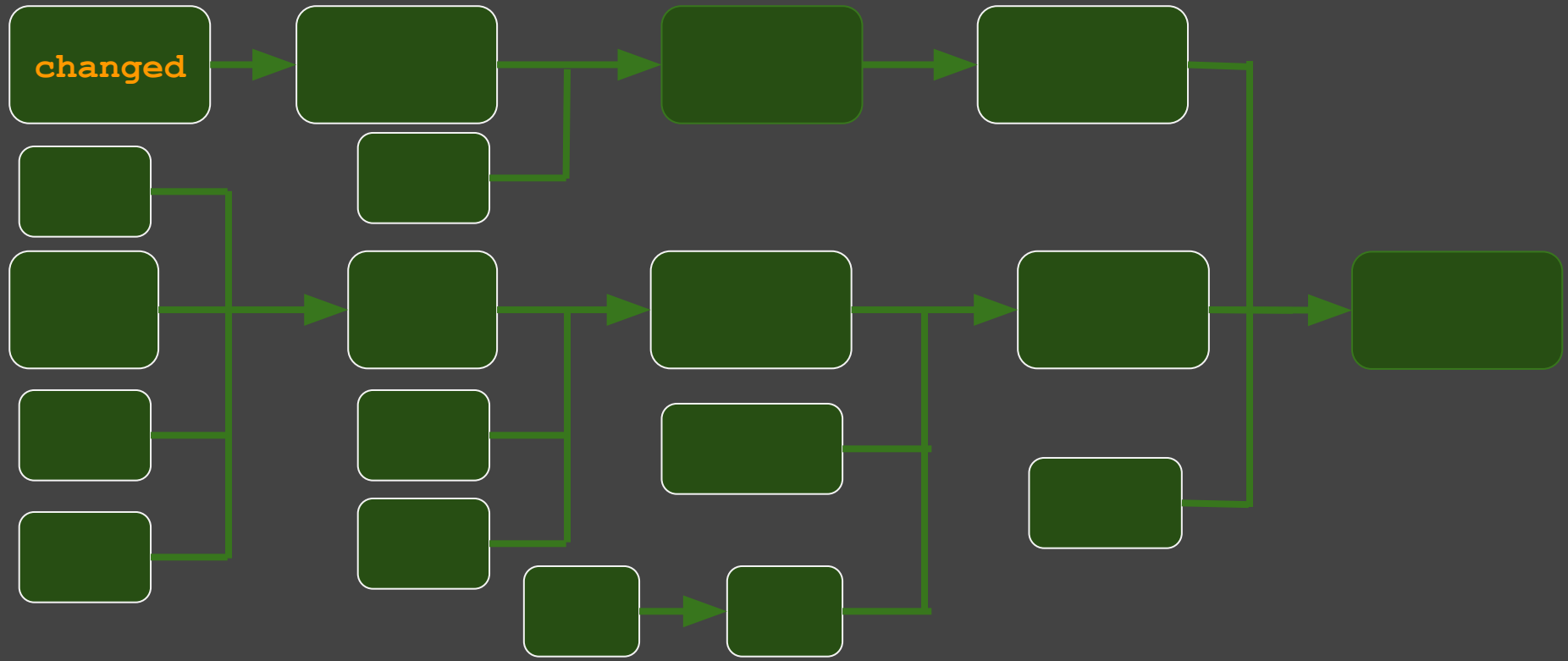


32 bit Compiling and linking C files

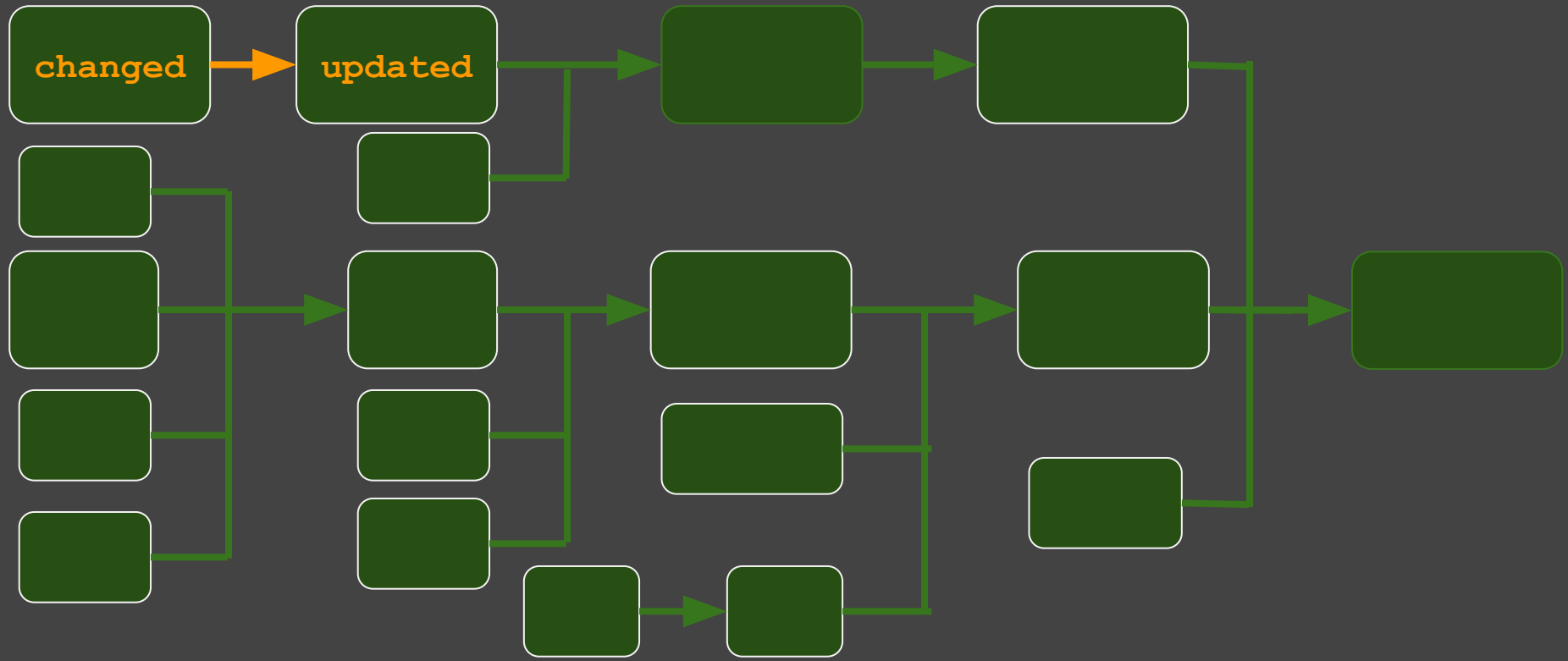
Building large projects



Building large projects



Building large projects



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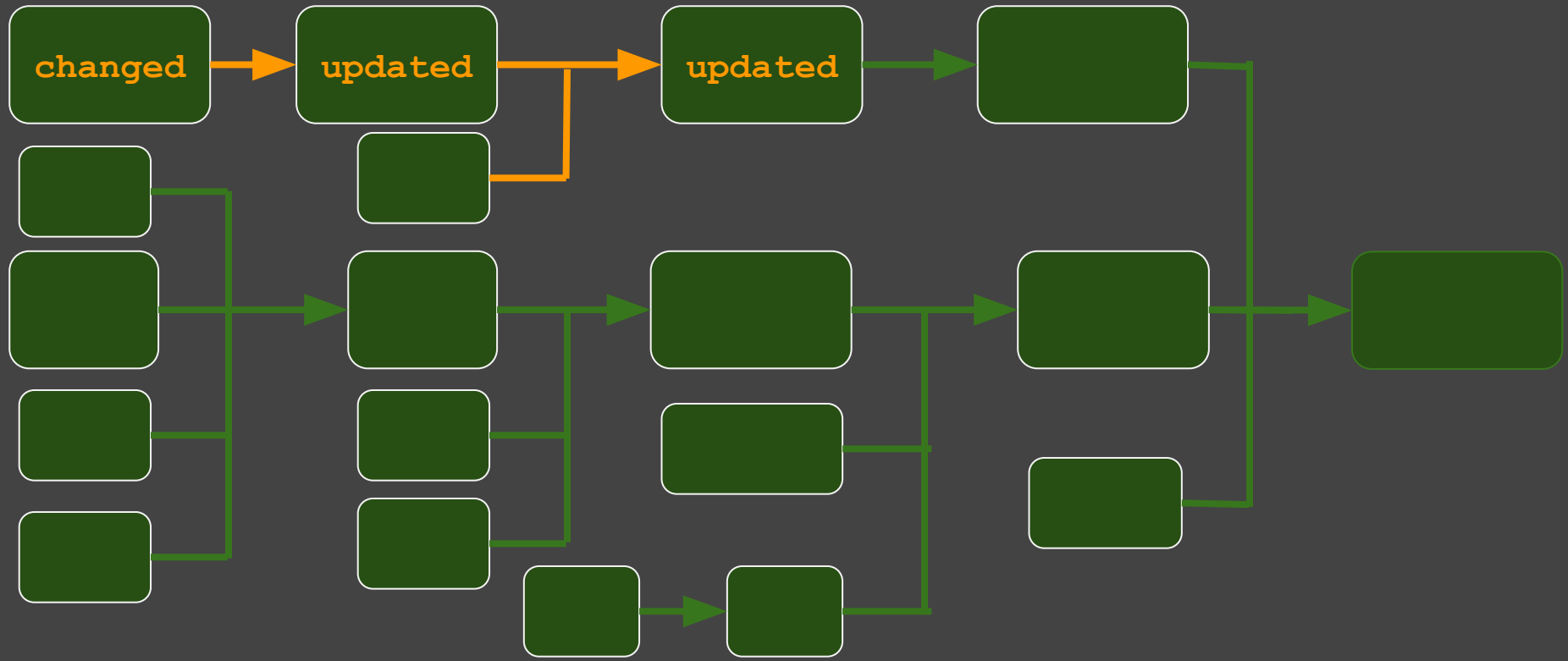

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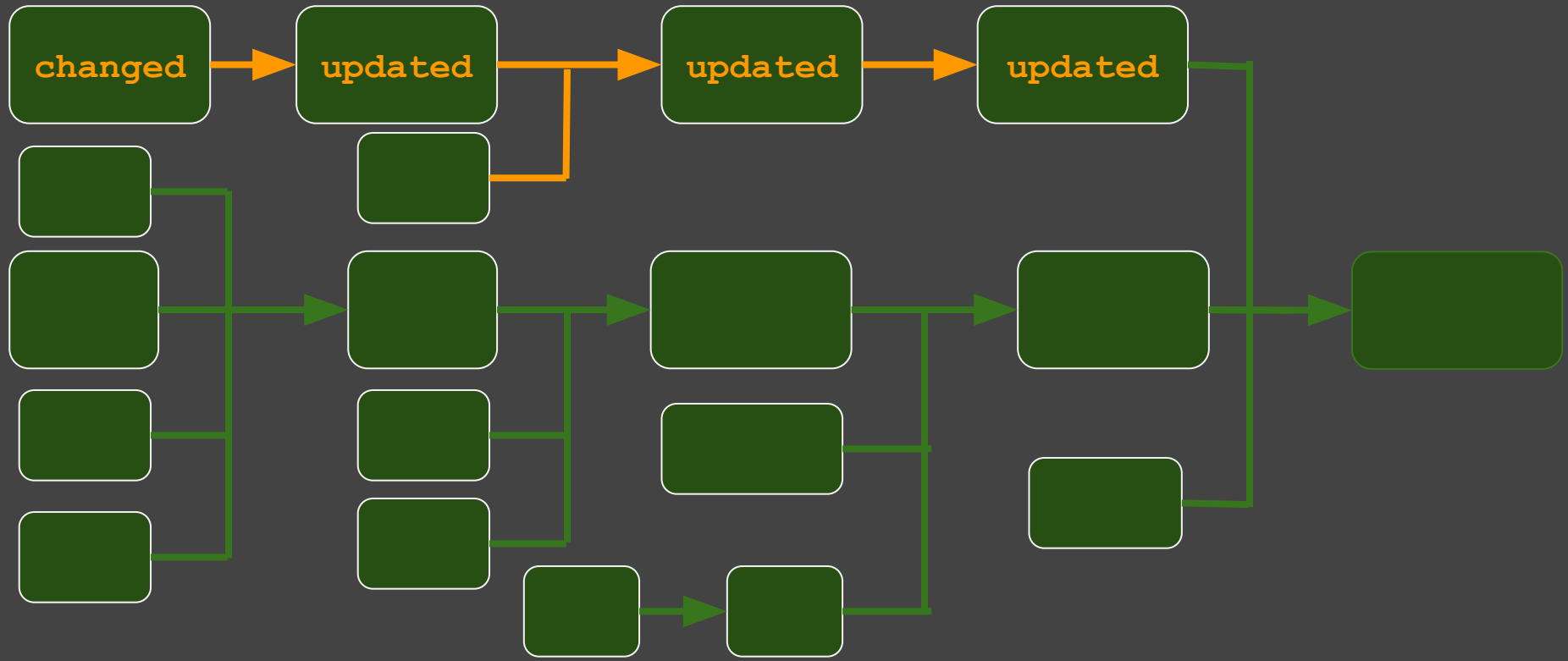
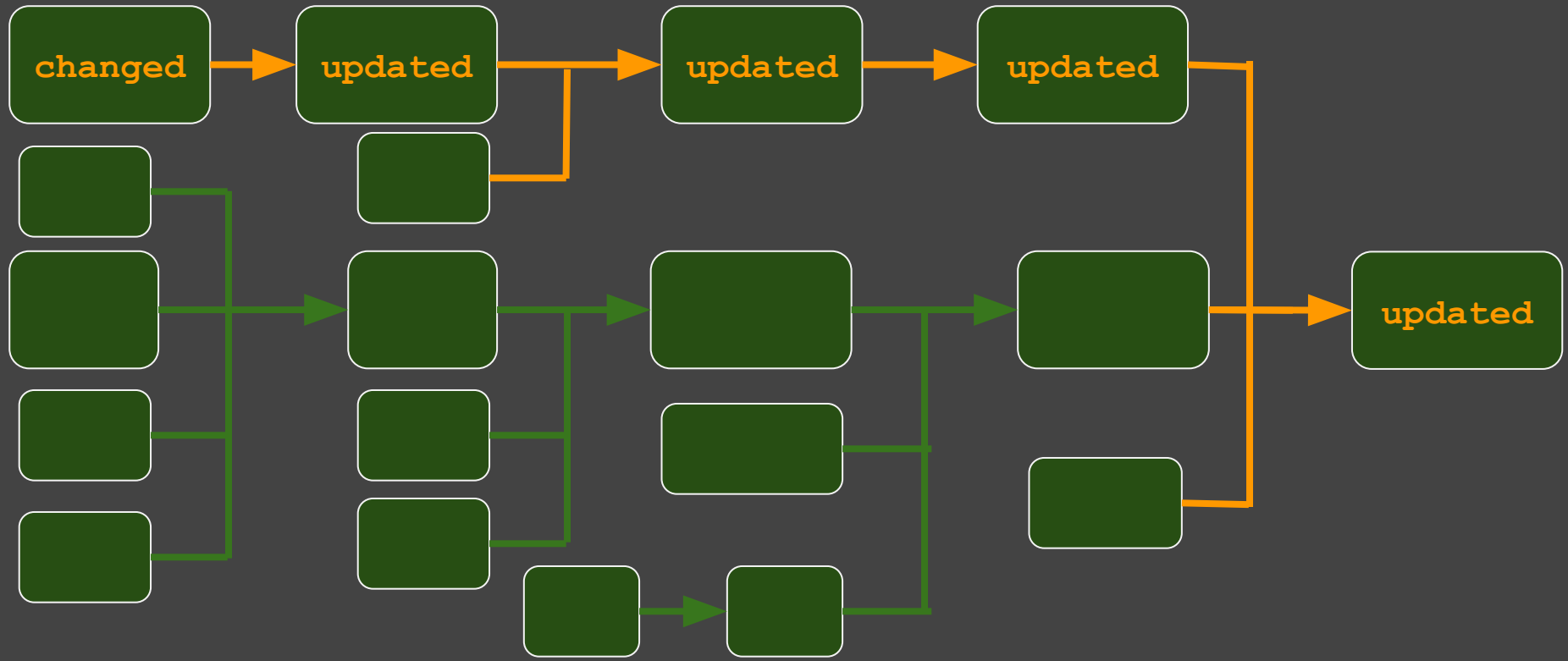
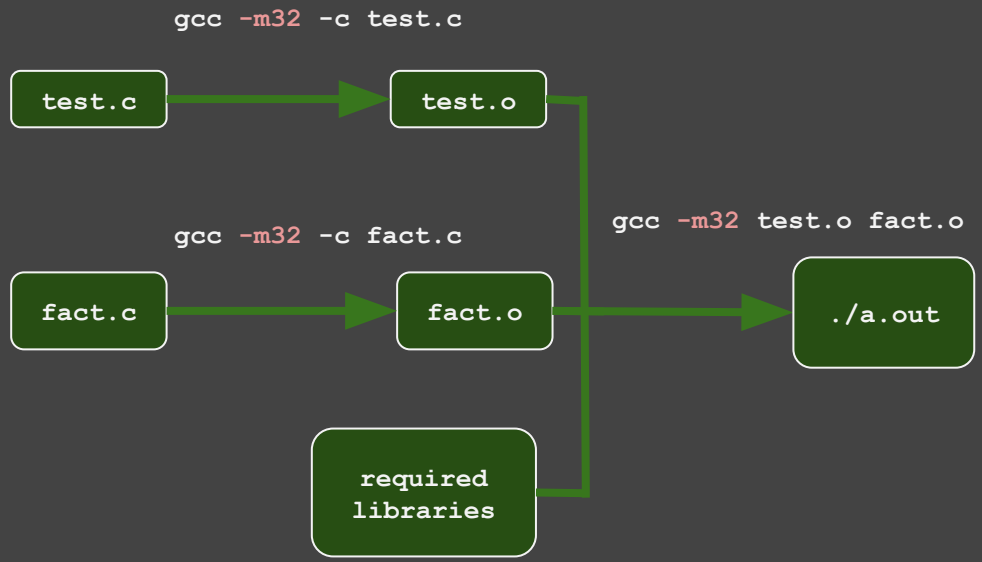


Building large projects



Makefile



target

Makefile

```
a.out: test.o fact.o
        gcc -m32 test.o fact.o

test.o: test.c
        gcc -m32 -c test.c

fact.o: fact.c
        gcc -m32 -c fact.c
```

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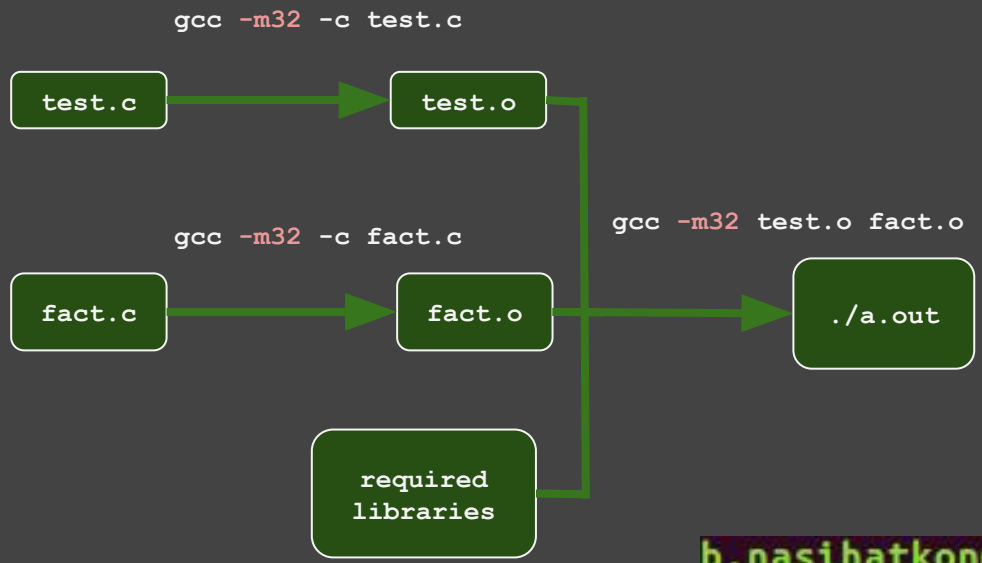
Makefile



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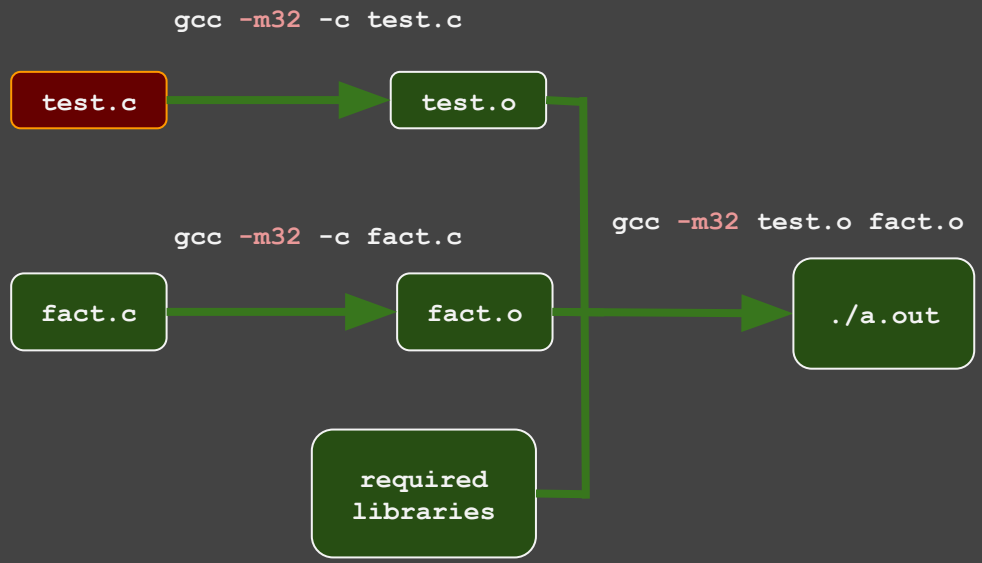
	gcc -m32 test.o fact.o

test.o: test.c
	gcc -m32 -c test.c

fact.o: fact.c
	gcc -m32 -c fact.c
```

```
b.nasihatkon@kntu:modular_c$ make
gcc -m32 -c test.c
gcc -m32 -c fact.c
gcc -m32 test.o fact.o
```

Makefile



change test.c and run make again:

Makefile

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        gcc -m32 test.o fact.o

test.o: test.c
        gcc -m32 -c test.c

fact.o: fact.c
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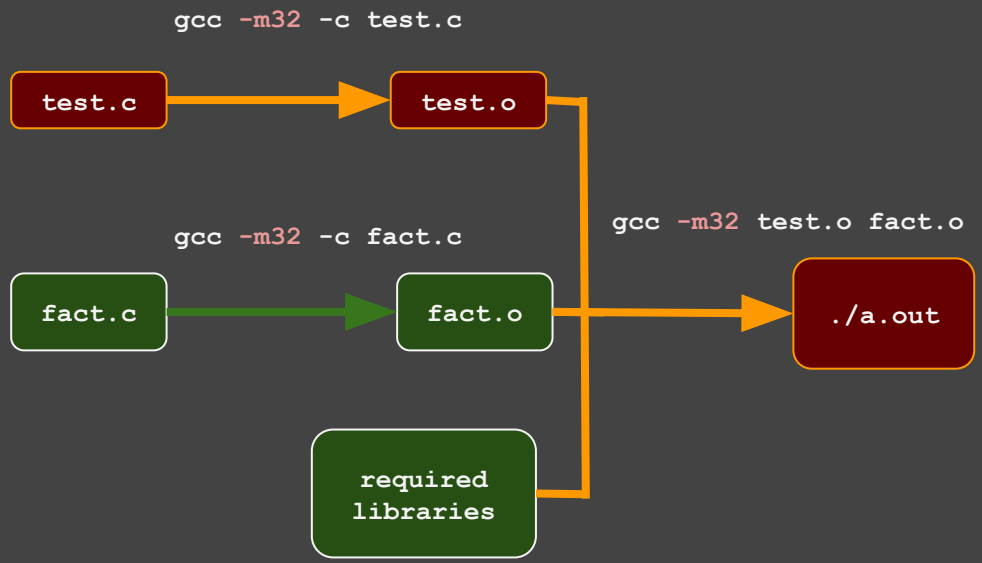
Makefile



Makefile

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a.out: test.o fact.o
	gcc -m32 test.o fact.o

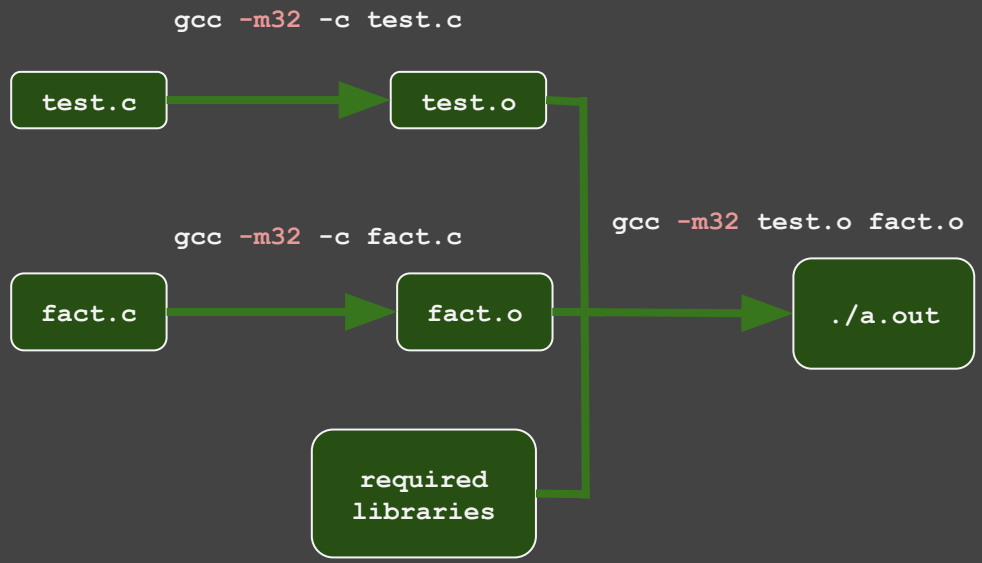
test.o: test.c
	gcc -m32 -c test.c

fact.o: fact.c
	gcc -m32 -c fact.c
```

change **test.c** and run make again:

```
b.nasihatkon@kntu:modular_c$ make
gcc -m32 -c test.c
gcc -m32 test.o fact.o
```

Makefile



change nothing and rerun make:

Makefile

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a.out: test.o fact.o
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test.o: test.c
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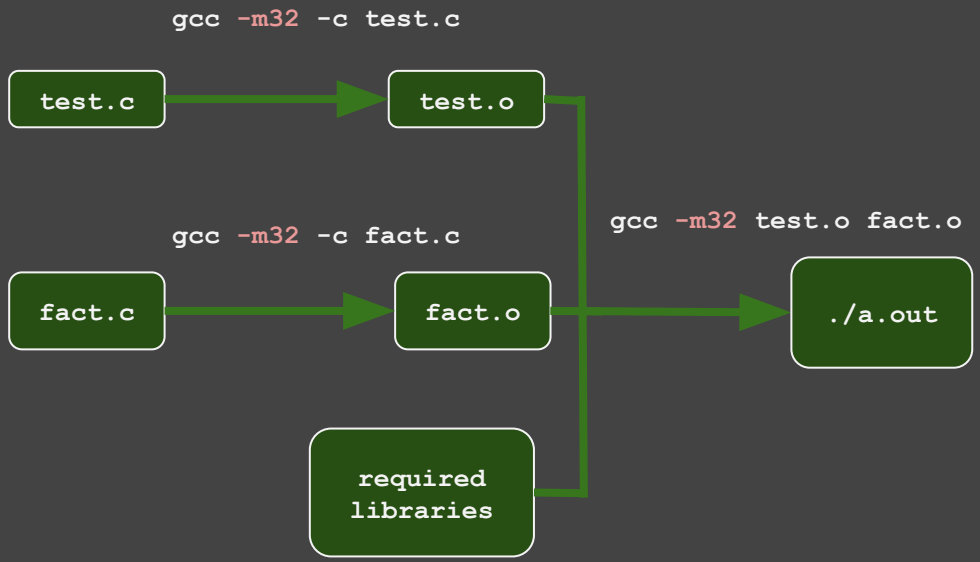
Makefile



Makefile

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a.out: test.o fact.o
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test.o: test.c
	gcc -m32 -c test.c

fact.o: fact.c
	gcc -m32 -c fact.c
```

change nothing and rerun make:

```
b.nasihatkon@kntu:modular_c$ make
make: 'a.out' is up to date.
```

Makefile

- More on Makefile
  - http://www.cs.colby.edu/maxwell/courses/tutorials/maketutor/
  - https://www.tutorialspoint.com/makefile/

Modular Programming in assembly

- Multiple object files
- We have already done it!

We have already done it!

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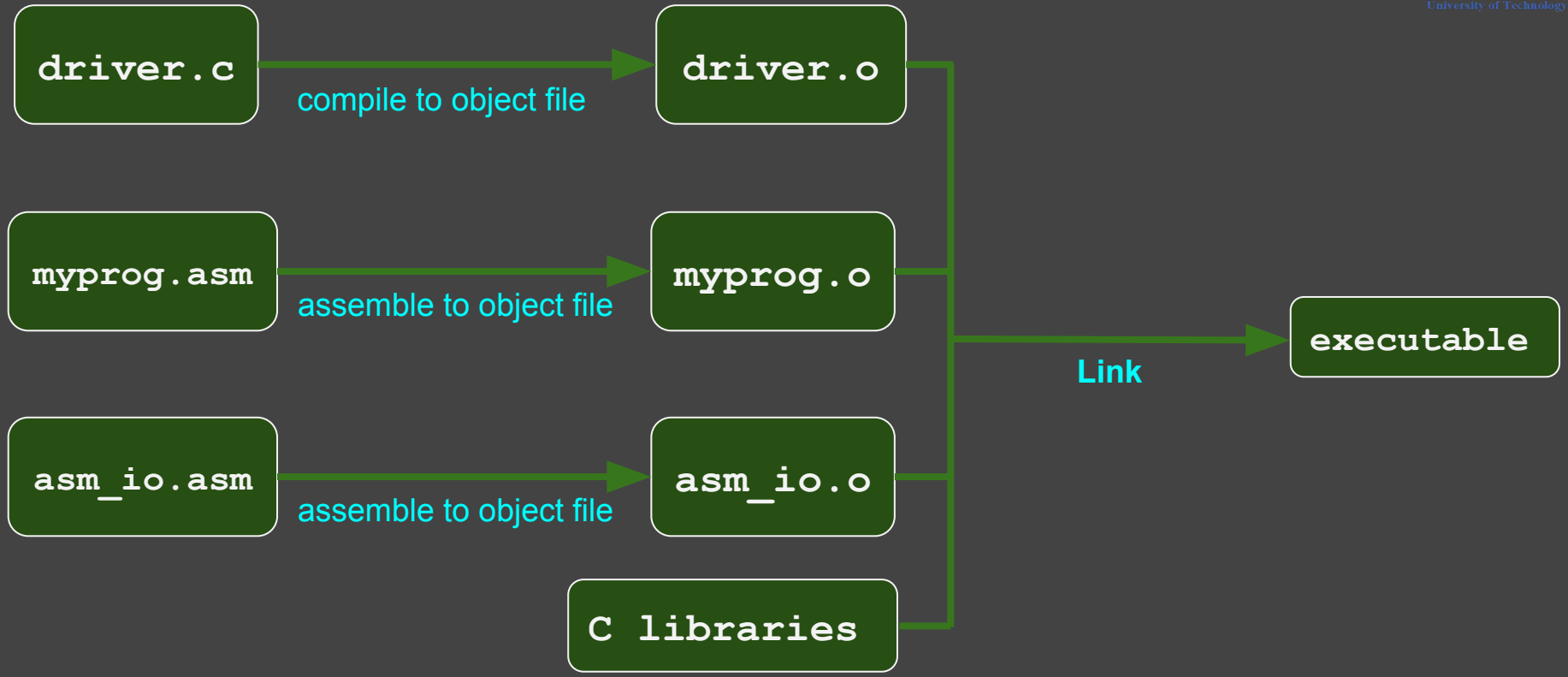
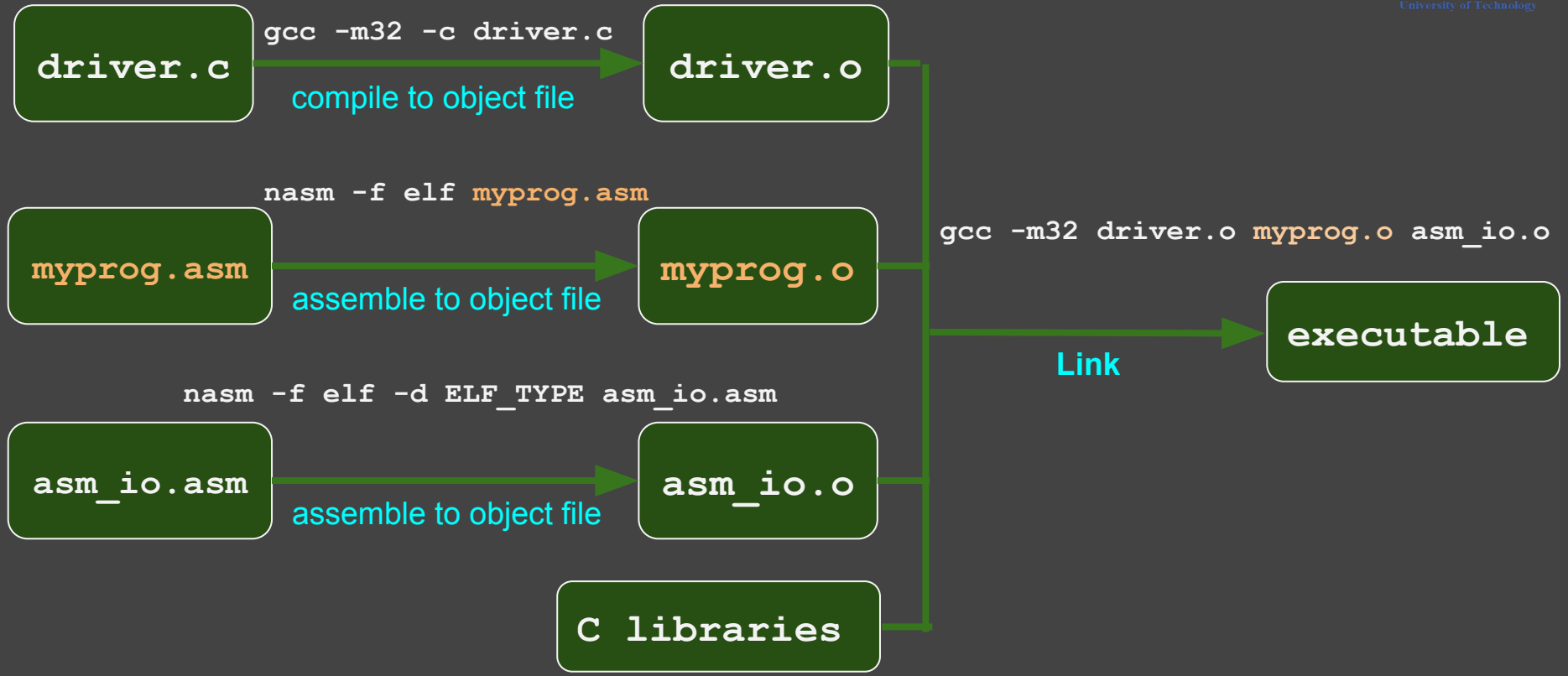


We have already done it!



Modular Programming in Assembly

first.asm

```
extern fact, var1

segment .text

    mov eax, [var1]

    ;; compute fact(6)
    push 6
    call fact
    add esp, 4
```

second.asm

```
global fact, var1

segment .data

var1:   dd  22


segment .text

fact:
    ;; factorial function
```

Modular Programming in Assembly

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segment .data

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Practice:

first.asm

```
%include "asm_io.inc"
segment .text
global asm_main
extern fact, var1

asm_main:
        pusha

        mov eax, [var1]
        call print_int
        call print_nl

        ;; compute fact(6)
        push 6
        call fact
        add esp, 4

        call print_int
        call print_nl

        popa
        ret
```

second.asm

```
global fact, var1
segment .data
var1:   dd  22

segment .text
fact:
        enter 0,0

        mov eax, [ebp+8]
        cmp eax, 0
        jg recur


        mov eax, 1
        jmp endfact
recur:
        dec eax
        push eax
        call fact
        add esp, 4

        imul dword [ebp+8]

endfact:
        leave
        ret
```

Practice:

first.asm

```
%include "asm_io.inc"
segment .text
global asm_main
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asm_main:
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Practice:

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Practice:

first.asm

```
%include "asm_io.inc"
segment .text
```

second.asm

```
global fact, var1
segment .data
var1:   dd  22

segment .text
fact:
```

How to assemble & link?

```
$ nasm -f elf first.asm
$ nasm -f elf second.asm
$ gcc -m32 -o first driver.c first.o second.o asm_io.o
```

How to run?

```
$ ./first
```

```
    call print_nl

    popa
    ret
```

```
endfact:
    leave
    ret
```

Using Makefile

Makefile

```
GCC_OPTIONS= -m32
NASM_OPTIONS= -f elf

first: driver.o first.o second.o asm_io.o
	gcc $(GCC_OPTIONS) -o first driver.o first.o second.o asm_io.o

first.o: first.asm asm_io.inc
	nasm $(NASM_OPTIONS) first.asm

second.o: second.asm asm_io.inc
	nasm $(NASM_OPTIONS) second.asm

asm_io.o: asm_io.asm
	nasm $(NASM_OPTIONS) -d ELF_TYPE asm_io.asm

driver.o: driver.c
	gcc $(GCC_OPTIONS) -c driver.c
```

Using Makefile

Makefile

```
GCC_OPTIONS= -m32
NASM_OPTIONS= -f elf

first: driver.o first.o second.o asm_io.o
	gcc $(GCC_OPTIONS) -o first driver.o first.o second.o asm_io.o

first.o: first.asm asm_io
	nasm $(NASM_OPTIONS

second.o: second.asm asm_
	nasm $(NASM_OPTIONS

asm_io.o: asm_io.asm
	nasm $(NASM_OPTIONS

driver.o: driver.c
	gcc $(GCC_OPTIONS)
```

```
b.nasihatkon@kntu:lecture11$ ls
1.html           driver.c        Makefile    second.asm
asm_io.asm       first           modular_c   second.asm.html
asm_io.asm.html  first.asm       README      template.asm
asm_io.inc       first.asm.html  run.sh      template.c
b.nasihatkon@kntu:lecture11$ make
gcc -m32 -c driver.c
nasm -f elf first.asm
nasm -f elf second.asm
nasm -f elf -d ELF_TYPE asm_io.asm
gcc -m32 -o first driver.o first.o second.o asm_io.o
b.nasihatkon@kntu:lecture11$ ./first
22
720
b.nasihatkon@kntu:lecture11$ make
make: 'first' is up to date.
b.nasihatkon@kntu:lecture11$
```

Practice:

first.asm

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%include "asm_io.inc"
segment .text
global asm_main
extern fact, var1

asm_main:
        pusha

        mov eax, [var1]
        call print_int
        call print_nl

        ;; compute fact(6)
        push 6
        call fact
        add esp, 4

        call print_int
        call print_nl

        popa
        ret
```

second.asm

```
global fact, var1
segment .data
var1:   dd  22

segment .text
fact:
```

Why have not `print_int` and `print_nl` been defined as `extern`?

```
endfact:
        leave
        ret
```

Practice:

first.asm

```
%include "asm_io.inc"
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global asm_main
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asm_main:
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```

second.asm

```
global fact, var1
segment .data
var1:   dd  22

segment .text
fact:
```

Why have not `print_int` and `print_nl` been defined as `extern`?

- Look at asm_io.inc

```
endfact:
        leave
        ret
```

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Practice:

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global asm_main
extern fact, var1

asm_main:
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        mov eax, [var1]
        call print_int
        call print_nl

        ;; compute fact(6)
        push 6
        call fact
        add esp, 4

        call print_int
        call print_nl

        popa
        ret
```

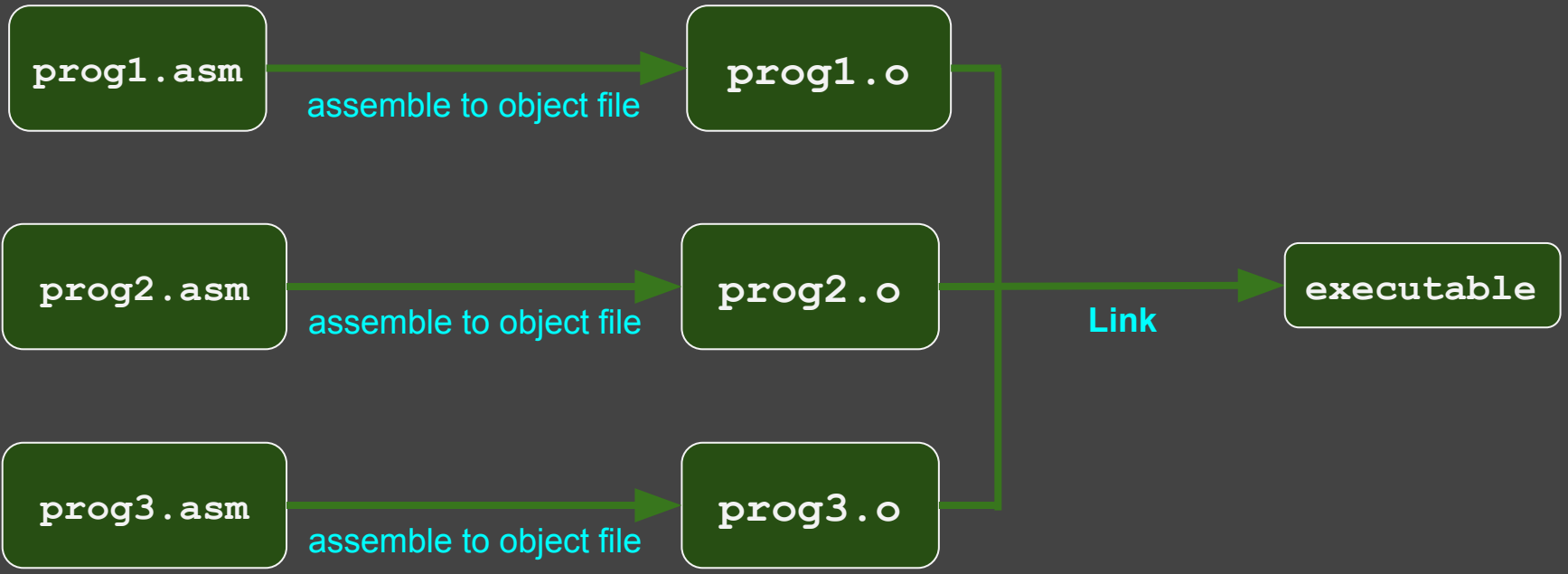
asm_io.inc

```
extern  read_int, print_int, print_uint, print_string
extern  read_char, print_char, print_nl
extern  sub_dump_regs, sub_dump_mem, sub_dump_math, sub_dump_stack

%macro  dump_regs 1
        push    dword %1
        call    sub_dump_regs
%endmacro

; usage: dump_mem label, start-address, # paragraphs
%macro  dump_mem 3
        push    dword %1
        push    dword %2
        push    dword %3
        call    sub_dump_mem
%endmacro
        ⋮
        ⋮
```

Standalone assembly programs (32-bit)



Standalone assembly programs (32-bit)

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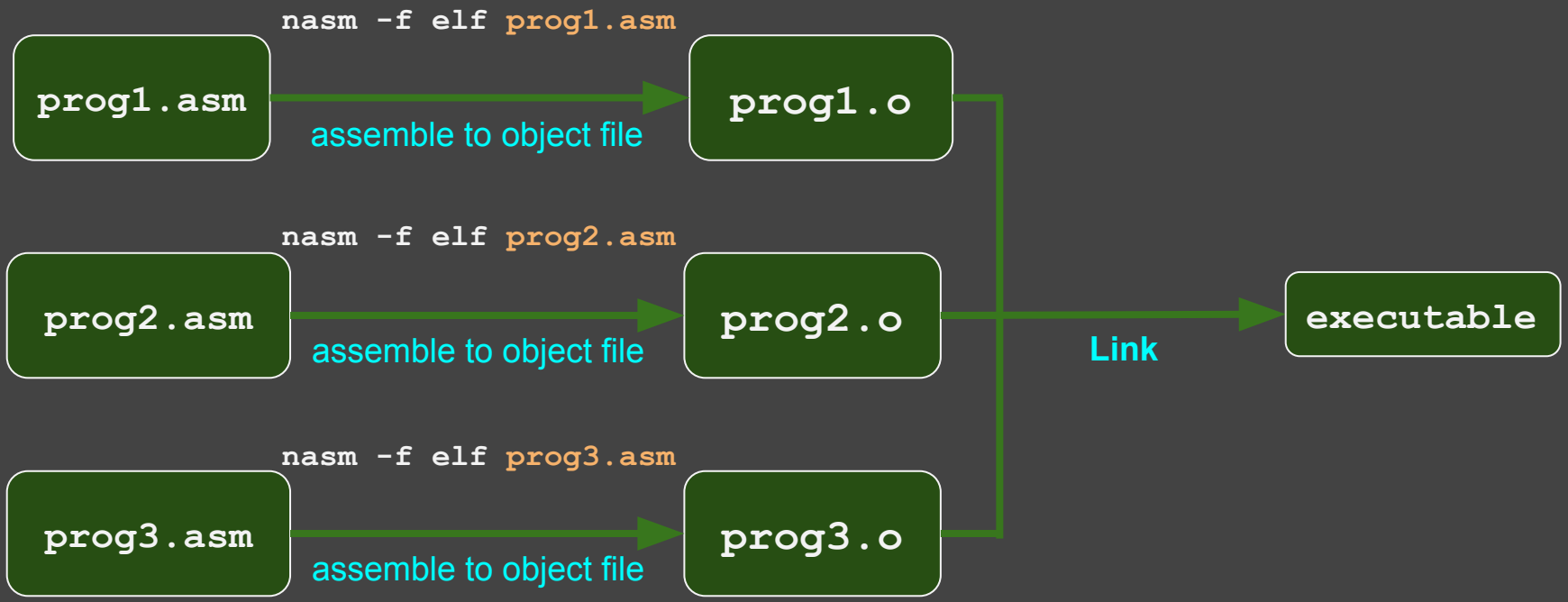
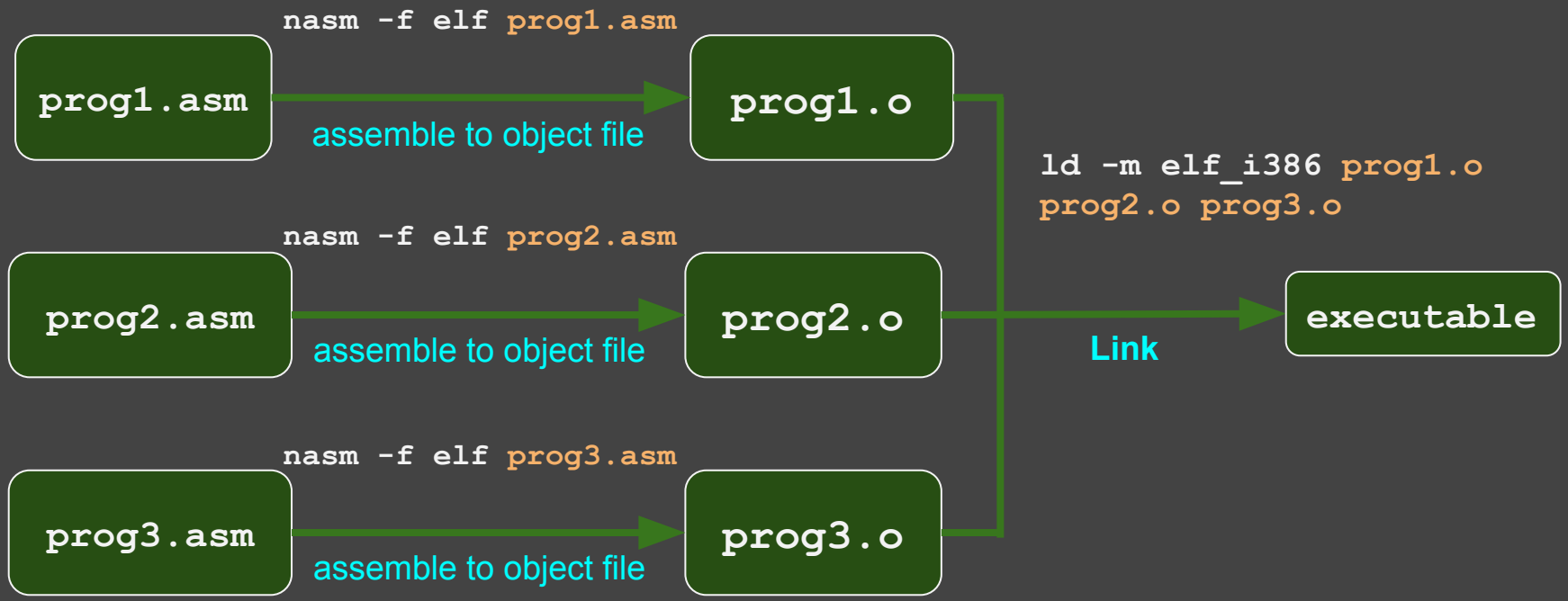


Standalone assembly programs (32-bit)



Standalone assembly programs (64-bit)

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