Introduction to 8086 Assembly

Lecture 3

Object files, compiling, assembling and linking

Compiling a C file

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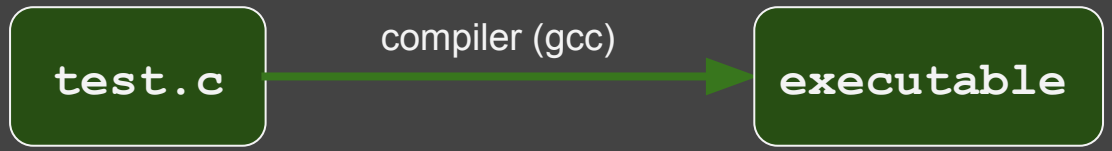

Compiling a C file, object files

Object files, libraries and linking

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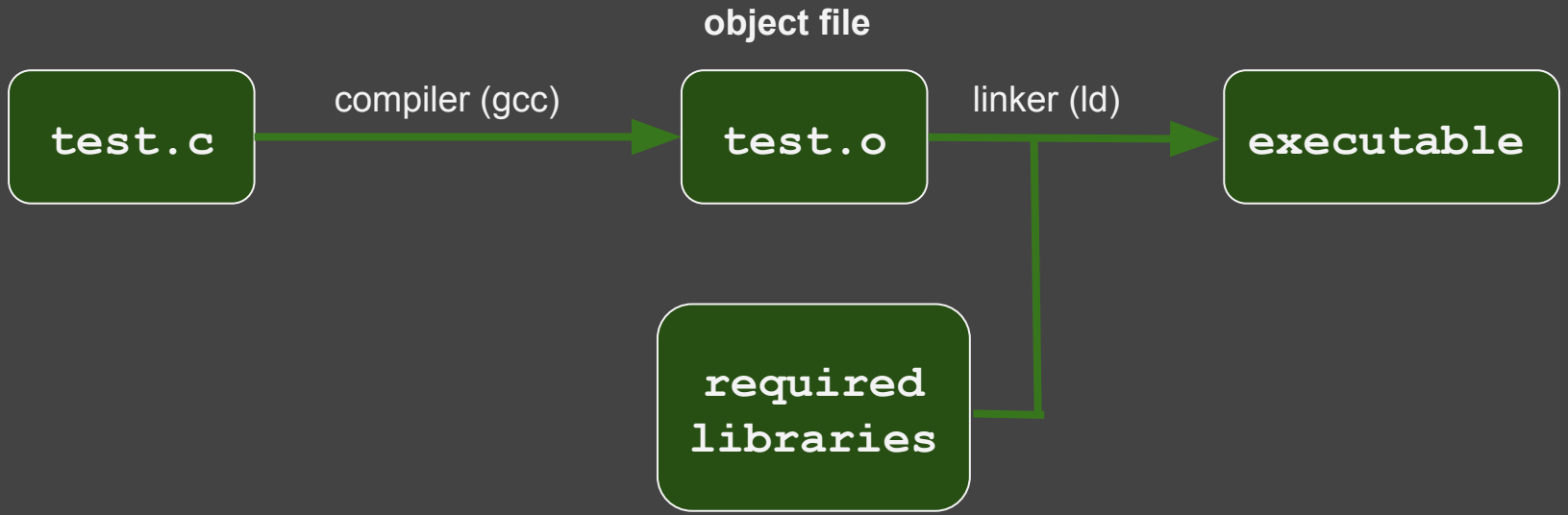

Modular programming in C

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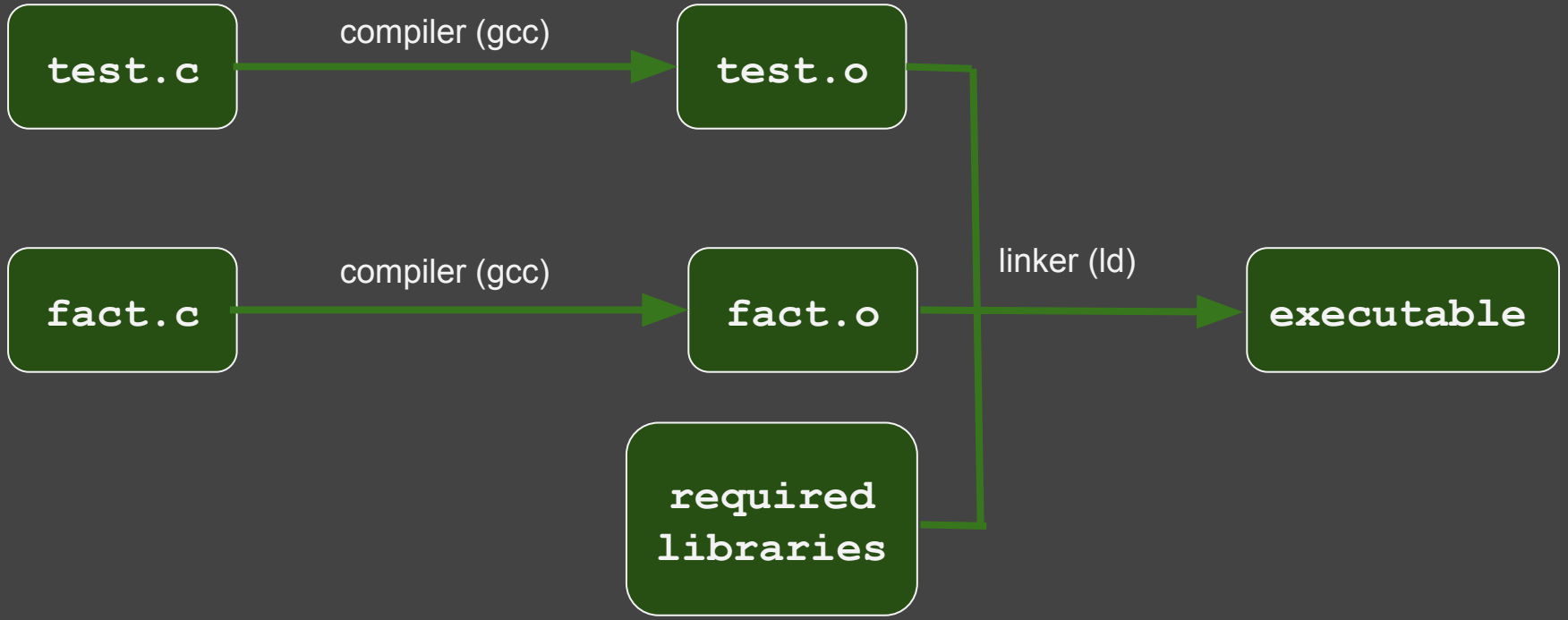
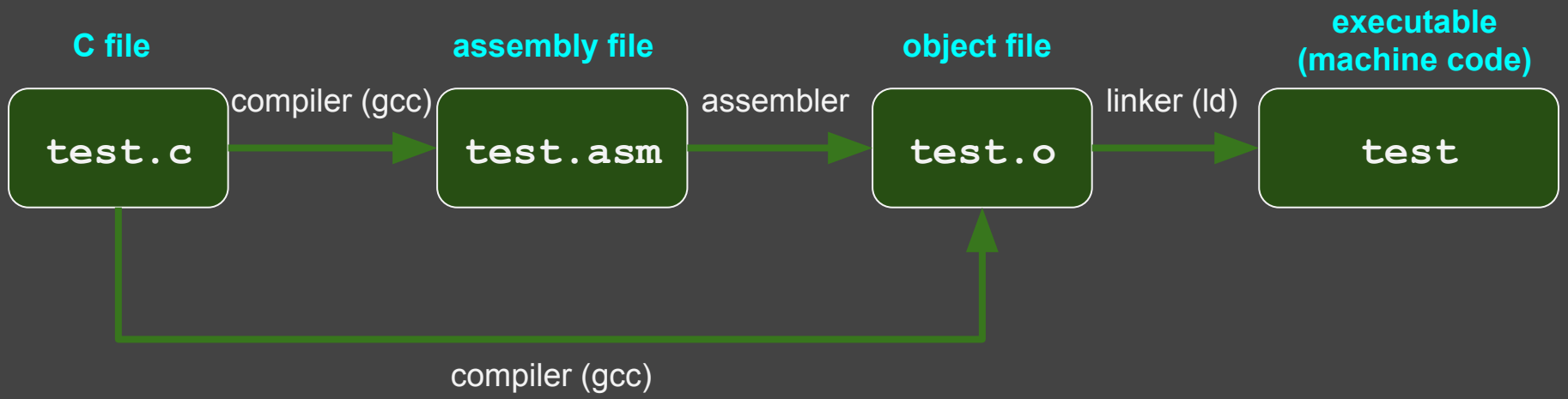


high-level to low-level hierarchy



Object files

- Machine code + metadata (unresolved symbols, etc.)
  - for linking, debugging, etc.
  - https://en.wikipedia.org/wiki/Object_file
  - https://en.wikipedia.org/wiki/Object_code
- Object file formats
  - Common Object File Format (COFF)
  - Relocatable Object Module Format (OMF)
  - **Executable and Linkable Format (ELF)**

Assembling assembly files

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Our first assembly program (64 bit)


```
segment   .data
msg:  db        "Salaaaaaaam!!", 10  ; message + newline character

global    _start

segment   .text
_start:                  ; entry point (linker needs this)

        mov   rax, 1     ; system call number (sys_write=1)
        mov   rdi, 1     ; file descriptor (stdout=1)
        mov   rsi, msg   ; message to write
        mov   rdx, 14    ; number of bytes to write

        syscall          ; invoke system call (sys_write)



        mov   rax, 60  ; system call number (sys_exit=60)
        mov   rdi, 0   ; exit code 0

        syscall        ; invoke system call (sys_exit)
```

look at: http://cs.lmu.edu/~ray/notes/nasmtutorial/

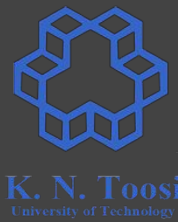
Our first assembly program (64 bit)


```
segment   .data
msg:  db        "Salaaaaaaam!!", 10  ; message + newline character

global    _start

segment   .text
_start:                     ; entry point (linker needs this)

        mov   rax, 1        ; system call number (sys_write=1)
        mov   rdi, 1        ; file descriptor (stdout=1)
        mov   rsi, msg      ; message to write
        mov   rdx, 14       ; number of bytes to write

        syscall             ; invoke system call (sys_write)



        mov   rax, 60   ; syst
        mov   rdi, 0    ; exii

        syscall             ; invoke system call (sys_exit)
```

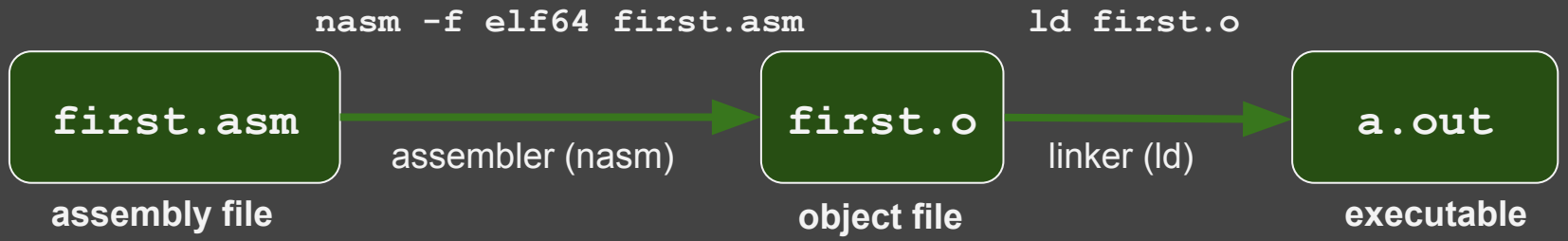
```
b.nasihatkon@kntu:lecture3$ nasm -f elf64 first.asm
b.nasihatkon@kntu:lecture3$ ld first.o
b.nasihatkon@kntu:lecture3$ ./a.out
Salaaaaaaam!!
```

look at: http://cs.lmu.edu/~ray/notes/nasmtutorial/

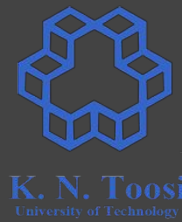
Assembling, linking and running (64 bit)



- **Assemble:** `nasm -f elf64 first.asm`
- **Link:** `ld first.o`
- **Execute:** `./a.out`



Assembling, linking and running (64 bit)

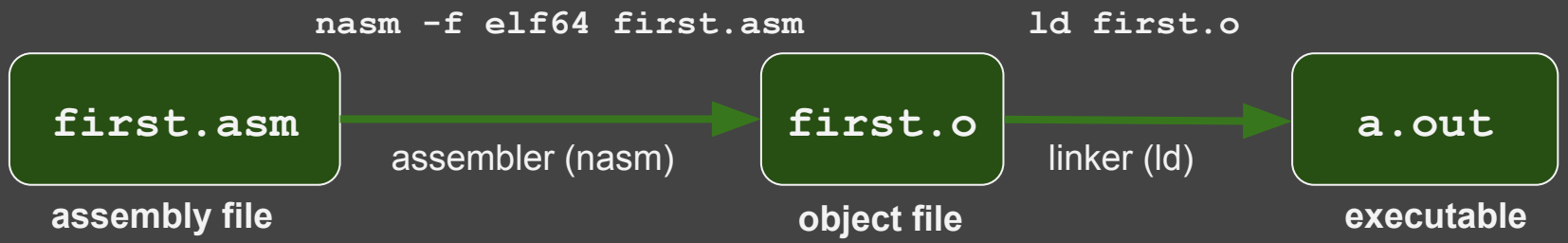


assembler

create 64 bit ELF object file format

input assembly file

```
nasm -f elf64 first.asm
```



Our first assembly program (32 bit)


```
segment .data
msg:  db        "Salaaaaaaam!!", 10  ; message + newline character

segment .text
   global _start     ; make entry point visible

_start:              ; entry point (linker needs this)
   mov  edx, 14      ; message length
   mov  ecx, msg     ; address of message to write
   mov  ebx, 1       ; file descriptor (stdout=1)
   mov  eax, 4       ; (32 bit) system call number (sys_write=4)
   int  0x80         ; interrupt no. x80 = system call

   mov  eax,1        ; (32 bit) system call number (sys_exit=1)
   int  0x80         ; interrupt no. x80 = system call
```

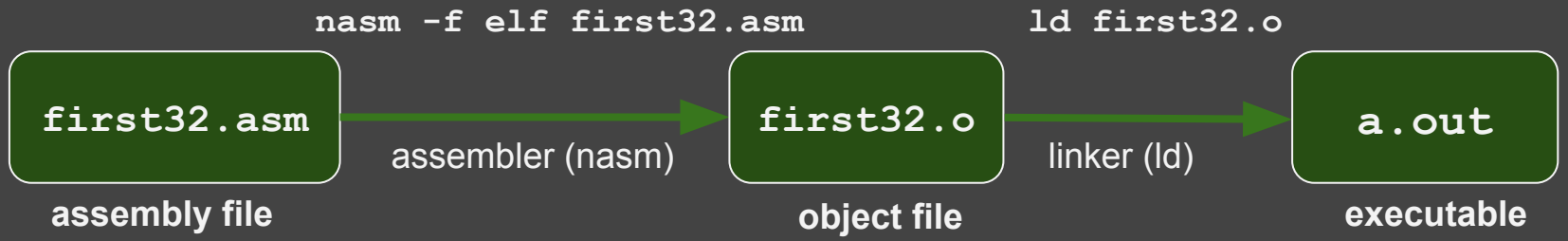
Our first assembly program (32 bit)


```
segment .data
msg:  db        "Salaaaaaaam!!", 10  ; message + newline character

segment .text
   global _start     ; make entry point visible

_start:              ; entry point (linker needs this)
   mov  edx, 14      ; message length
   mov  ecx, msg     ; address of message to write
   mov  ebx, 1       ; file descriptor (stdout=1)
   mov  eax, 4       ; (32 bit) system call number (sys_write=4)
   int  0x80         ; interrupt no. x80 = system call

   mov  eax,1        ; (32 bit) system call number (sys_exit=1)
   int  0x80         ; interrup
```

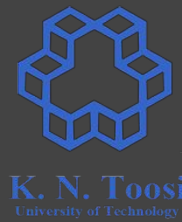
```
nasihatkon@kntu:lecture3$ nasm -f elf first32.asm
nasihatkon@kntu:lecture3$ ld -m elf_i386 first32.o
nasihatkon@kntu:lecture3$ ./a.out
Salaaaaaaam!!
```

Assembling, linking and running (64 bit)

- **Assemble:** `nasm -f elf first32.asm`
- **Link:** `ld -m elf_i386 first32.o`
- **Execute:** `./a.out`



Assembling, linking and running (64 bit)

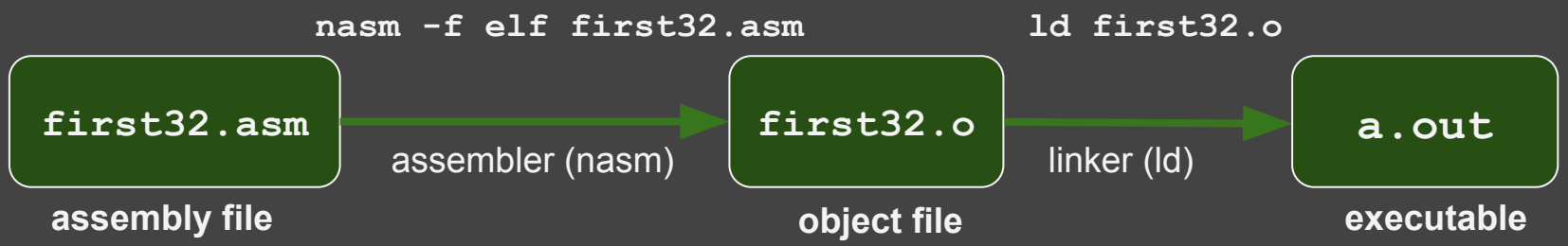


assembler

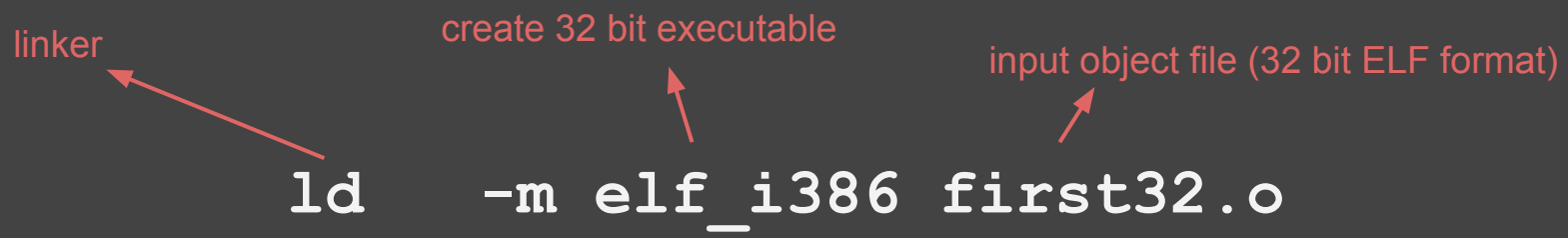
create 32 bit ELF object file format

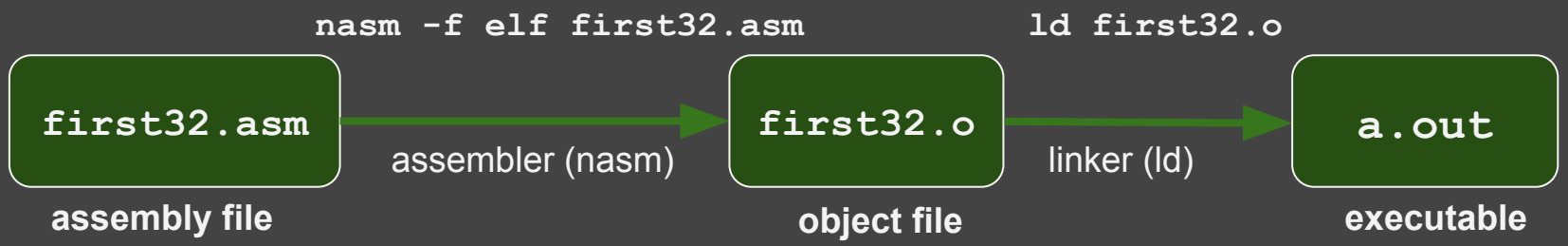
input assembly file

```
nasm  -f elf  first32.asm
```



Assembling, linking and running (64 bit)





Compiling and linking C files

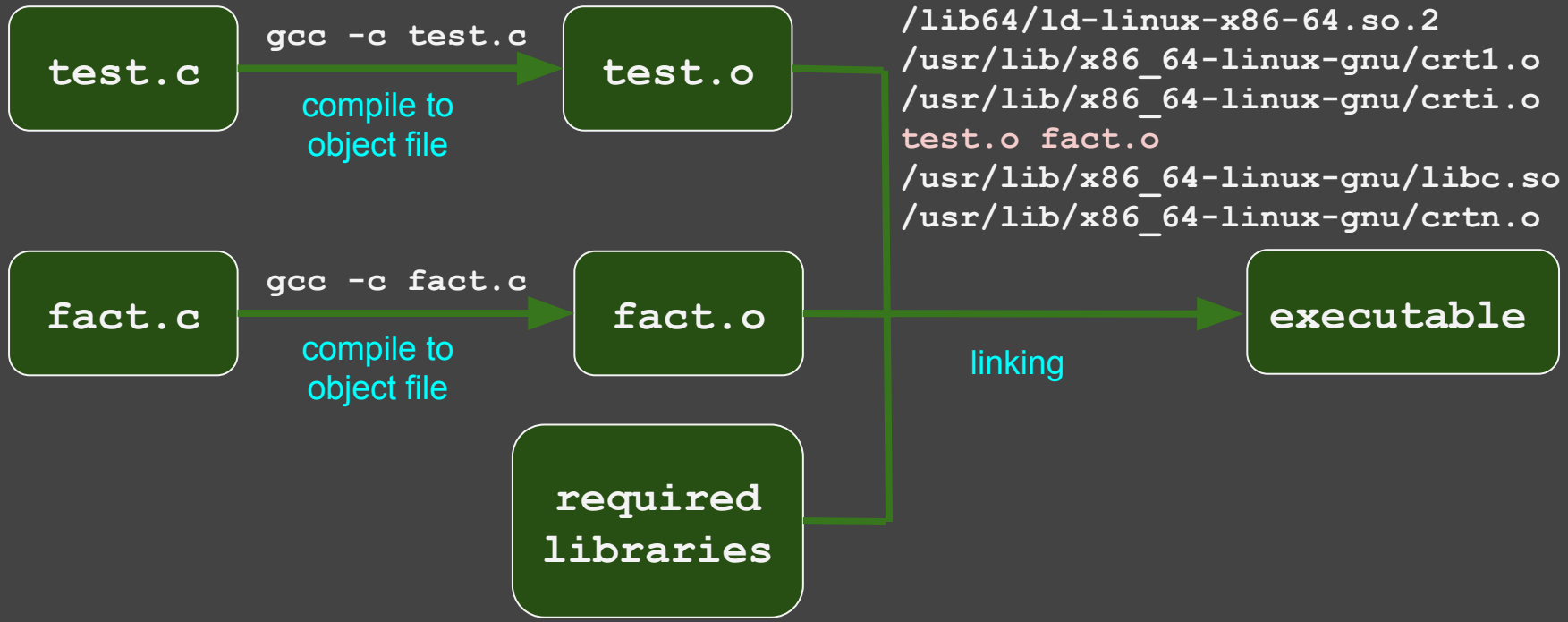
test.c

```c
#include <stdio.h>

int fact(int);

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

  return  0;
}
```

fact.c

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

Compiling and linking C files



Compiling and linking C files

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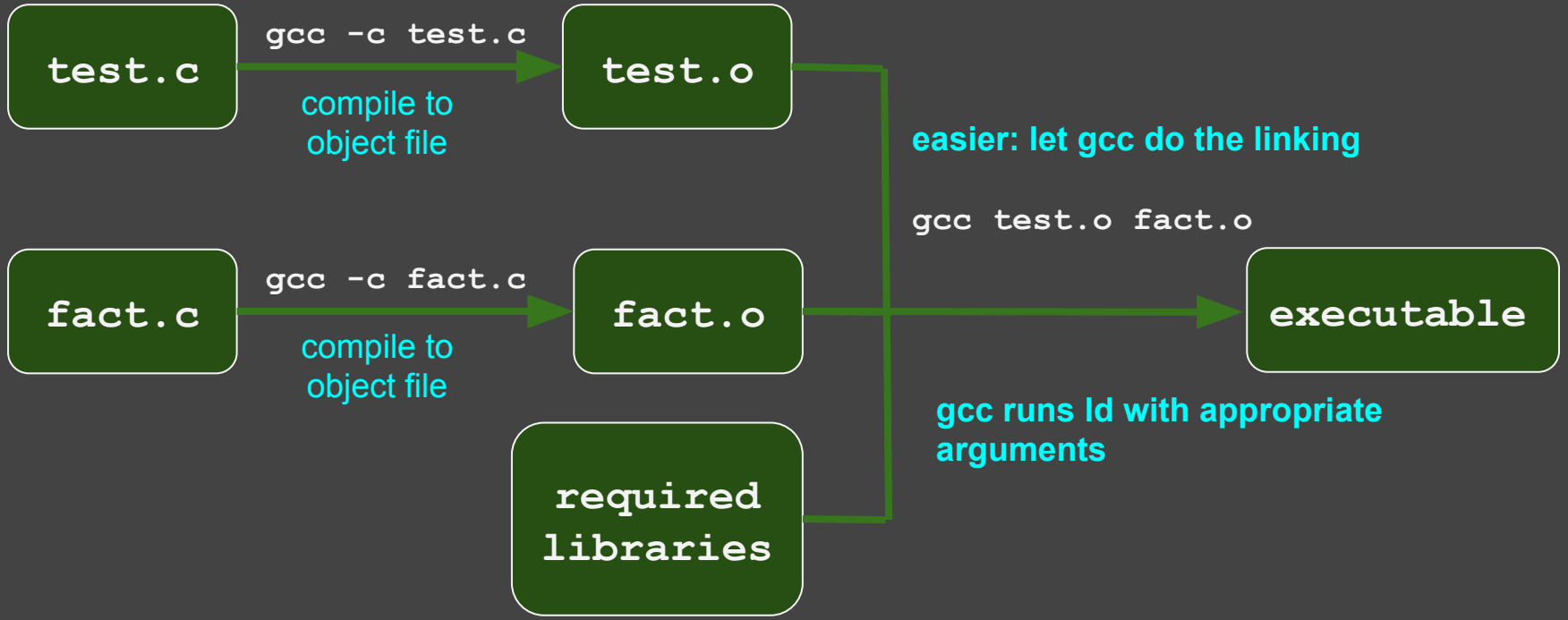
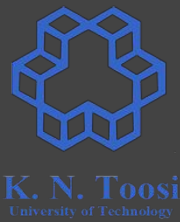


Compiling C files to 32 bit apps



Compile to 32 bit executable on a 64 bit system:

- First, install the 32 bit libraries:
  - `sudo apt-get install libc6-dev-i386`
  - `sudo apt-get install libx32gcc-4.8-dev`
  - `sudo apt-get install gcc-multilib`
- You might need to install:
  - `sudo apt-get install gcc-6-multilib`

32 bit Compiling and linking C files

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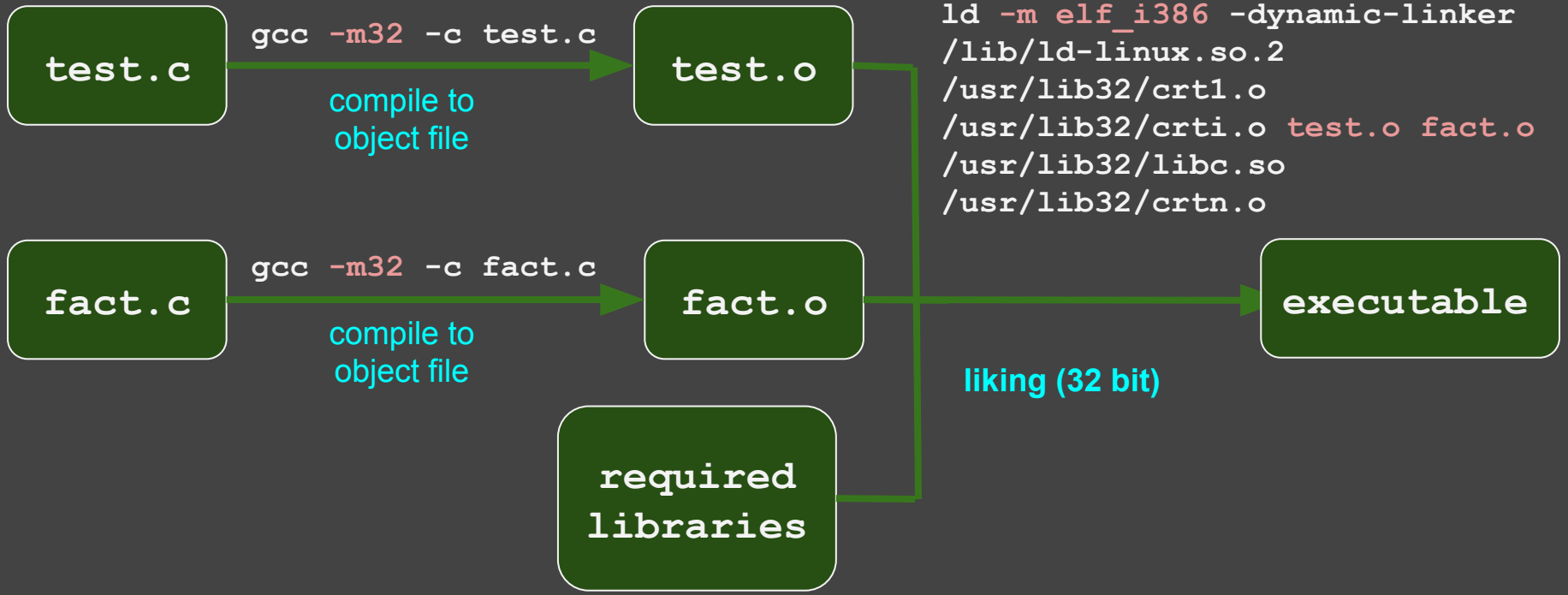
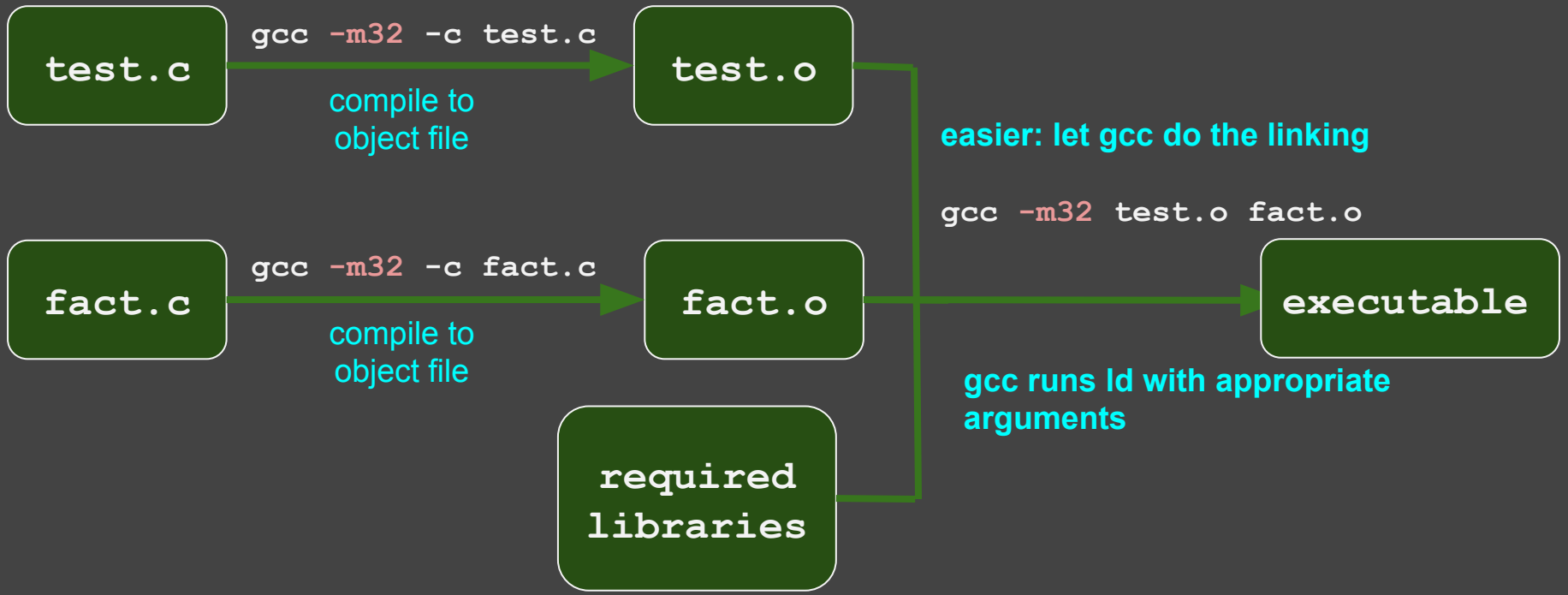
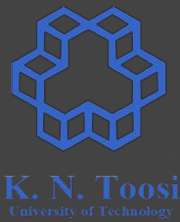


32 bit Compiling and linking C files



Our second assembly program!



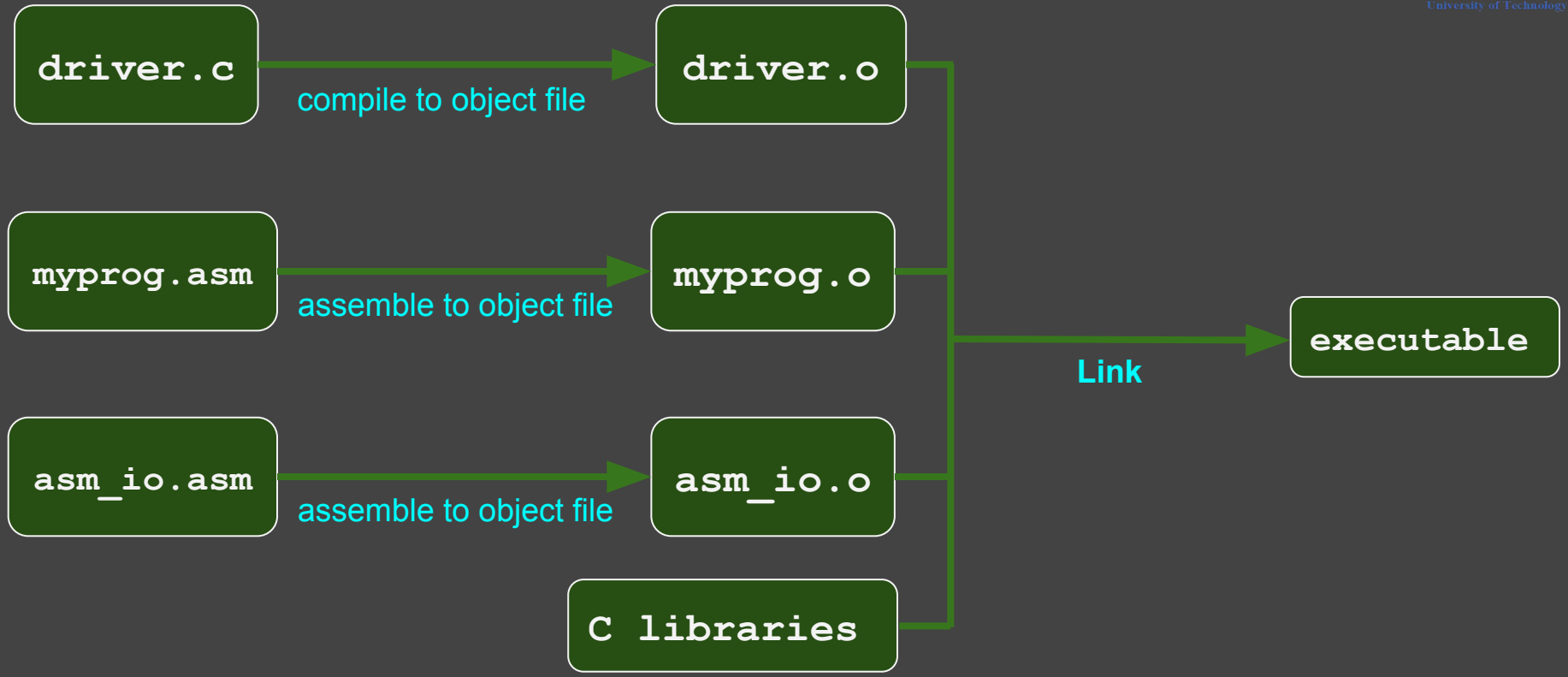
- We do (mostly) 32 bit assembly
- We use the functions/macros from the book (Carter, PC Assembly Language, 2007) for IO

I/O functions and macros from the book

`call print_int`	prints EAX as singed integer
`call print_char`	prints the character whose ascii code is stored in AL
`call print_string`	prints the string whose starting address is stored in EAX, string must be null-terminated (C-string)
`call print_nl`	prints a newline character
`call read_int`	reads an integer from standard input and stores it into EAX
`call read_char`	read a character from standard input and stores its ascii code in EAX
`dump_regs <num>`	(MACRO) prints out values of registers and flags (<num> is some number like 12 making debugging easier)

Carter, *PC Assembly Language*, 2007.

Our second assembly program!



steps to run our program

0. Install the Netwide Assembler
   - `sudo apt install nasm`
1. Download the example files (including IO files) from the books website: http://pacman128.github.io/pcasm/
   - for linux click on the link linux_examples to download the files
   - there are links for other platforms as well
2. Copy the files `asm_io.inc`, `asm_io.asm` and `cdecl.h` to your current working directory.
3. Compile the file asm_io.asm to object file (creating `asm_io.inc`)
   - `nasm -f elf -d ELF_TYPE asm_io.asm`
4. Create a file named `driver.c`

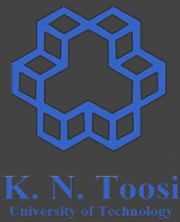
steps to run our program

4. Create a file named `driver.c` simply calling an assembly function:

```
void asm_main();

int main() {

    asm_main();

    return 0;
}
```

(alternatively, copy the files `driver.c` and `cdecl.h` to your current directory.)

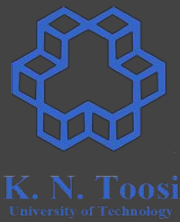
steps to run our program



5. Install the 32 bit C libraries (if not installed)
   - `sudo apt-get install libc6-dev-i386`
   - `sudo apt-get install libx32gcc-4.8-dev`
   - `sudo apt-get install gcc-multilib` **(if needed)**
   - `sudo apt-get install gcc-6-multilib` **(if needed)**

6. Compile driver.c to 32 bit object file (creating driver.o)
   - `gcc -m32 -c driver.c`

steps to run our program



7. Create your main assembly file containing the `asm_main` label
   - here the file named `myprog.asm` and looks like this:

```
%include "asm_io.inc"

segment .text

global asm_main

asm_main:
      enter 0,0
      pusha

      mov eax, 100
      mov ebx, 20
      sub eax, ebx

      call print_int    ; print EAX
      call print_nl     ; print a new line

      dump_regs 1111    ; printing the system state (registers, etc.)

      popa
      leave
      ret
```

steps to run our program

7. Create your main assembly file containing the `asm_main` label
   - here the file named `myprog.asm` and looks like this:

```
%include "asm_io.inc"

segment .text

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      mov eax, 100
      mov ebx, 20
      sub eax, ebx

      call print_int     ; print EAX
      call print_nl      ; print a new line

      dump_regs 1111     ; print registers, etc

      popa
      leave
      ret
```

myprog.asm

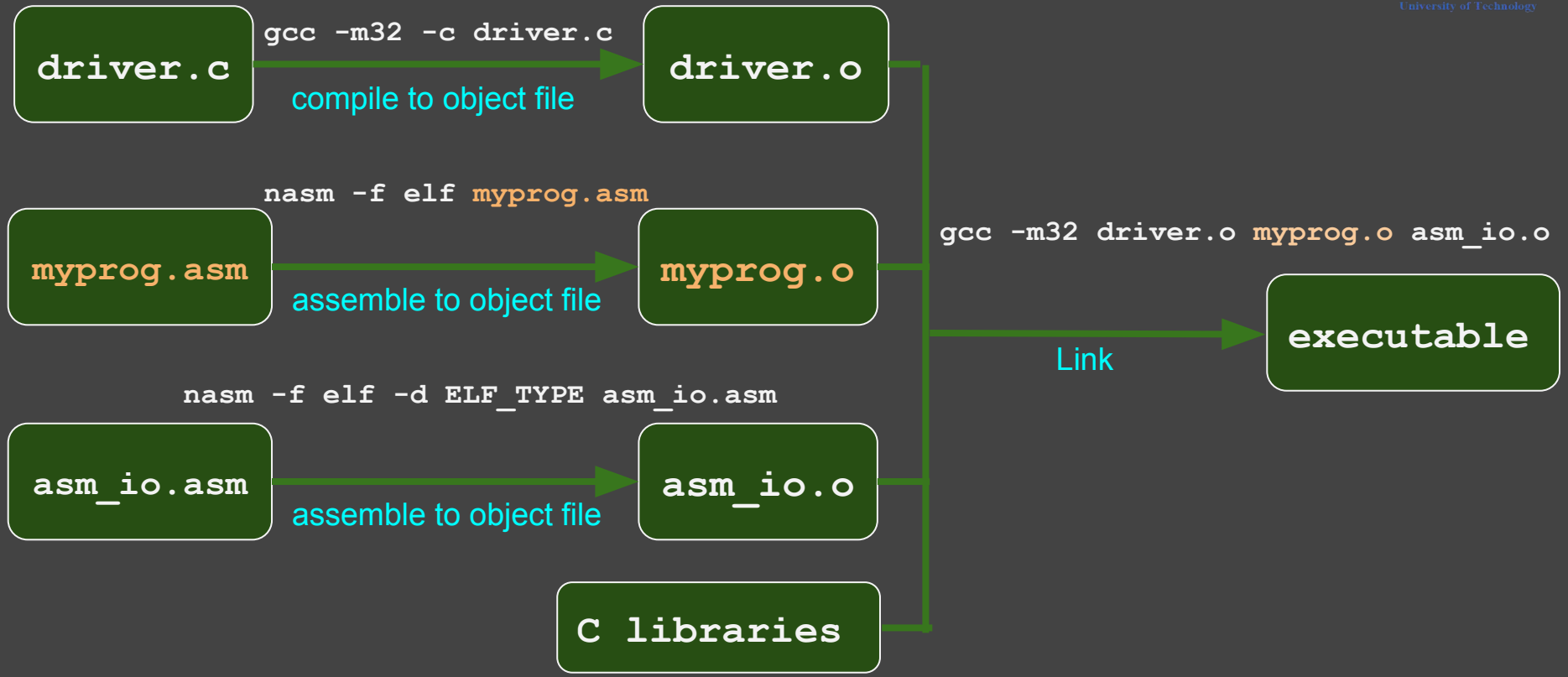
```
void asm_main();

int main() {

     asm_main();

     return 0;
}
```

driver.c

steps to run our program

8. Compile your assembly code to 32 bit object file (creating `myprog.o`)
   - `nasm -f elf myprog.asm`
9. link the object files `myprog.o`, `asm_io.o`, `driver.o` (and the C libraries) to create the executable
   - `gcc -m32 driver.o myprog.o asm_io.o`
10. run the executable and see the output
    - `./a.out`

steps to run our program



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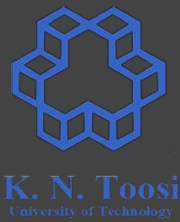
steps to run our program



myprog.asm

```
%include "asm_io.inc"

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global asm_main

asm_main:
      enter 0,0
      pusha

      mov eax, 100
      mov ebx, 20
      sub eax, ebx

      call print_int     ; print EAX
      call print_nl      ; print a n

      dump_regs 1111     ; print reg

      popa
      leave
      ret
```
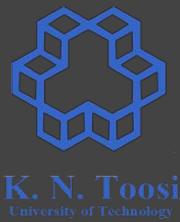

driver.c

```
void asm_main();

int main() {

     asm_main();

     return 0;
}
```

```
nasihatkon@kntu:lecture3$ nasm -f elf -d ELF_TYPE asm_io.asm
nasihatkon@kntu:lecture3$ gcc -m32 -c driver.c
nasihatkon@kntu:lecture3$ nasm -f elf myprog.asm
nasihatkon@kntu:lecture3$ gcc -m32 driver.o myprog.o asm_io.o
nasihatkon@kntu:lecture3$ ./a.out
80
Register Dump # 1111
EAX = 00000050 EBX = 00000014 ECX = FFDBFCB0 EDX = FFDBFCD4
ESI = F76B7000 EDI = F76B7000 EBP = FFDBFC88 ESP = FFDBFC68
EIP = 080484EB FLAGS = 0206                  PF
```

All commands

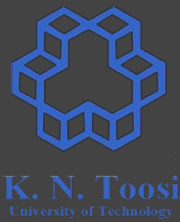



```
nasm -f elf -d ELF_TYPE asm_io.asm

gcc -m32 -c driver.c

nasm -f elf myprog.asm

gcc -m32 driver.o myprog.o asm_io.o

./a.out
```

Determine output file name (-o option)


```
nasm -f elf -d ELF_TYPE asm_io.asm

gcc -m32 -c driver.c

nasm -f elf myprog.asm

gcc -m32 driver.o myprog.o asm_io.o -o myprog

./myprog
```

All commands

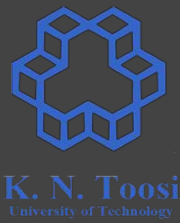


to make your life easier I have created a simple bash script named **run.sh**

run.sh

```
nasm -f elf -d ELF_TYPE asm_io.asm &&
gcc -m32 -c driver.c
nasm -f elf $1.asm &&
gcc -m32 -o $1 driver.c $1.o asm_io.o &&
./$1
```

All commands



to make your life easier I have created a simple bash script named **run.sh**

run.sh

```
nasm -f elf -d ELF_TYPE asm_io.asm &&
gcc -m32 -c driver.c
nasm -f elf $1.asm &&
gcc -m32 -o $1 driver.c $1.o asm_io.o &&
./$1
```

```
nasihatkon@kntu:lecture3$ ./run.sh myprog
80
Register Dump # 1111
EAX = 00000050 EBX = 00000014 ECX = FFE3E970 EDX = FFE3E994
ESI = F773B000 EDI = F773B000 EBP = FFE3E948 ESP = FFE3E928
EIP = 080484EB FLAGS = 0206                  PF
```

Writing your own program

- Take the same steps as above
- You source file should be like this (or use `skel.asm` from the book file)

```
%include "asm_io.inc"

segment .text

global asm_main

asm_main:
      enter 0,0
      pusha

      ; write your assembly code here!


      popa
      leave
      ret
```