Compiling C Code

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C Code

- Source Code

```
#include <stdlib.h>
#include <stdio.h>

int main(void) {
  printf("Hello world!\n");
  return EXIT_SUCCESS;
}
```

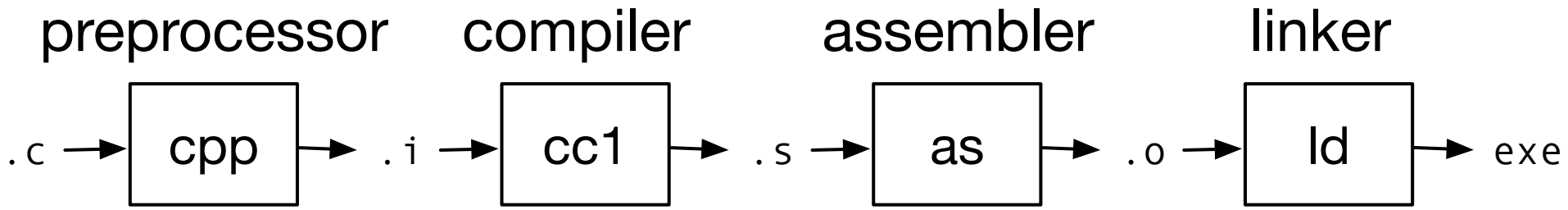
- Compile

```
linux> gcc -Og hello-world.c
```

- Execute

```
linux> ./a.out
Hello world!
```

Compilation Steps



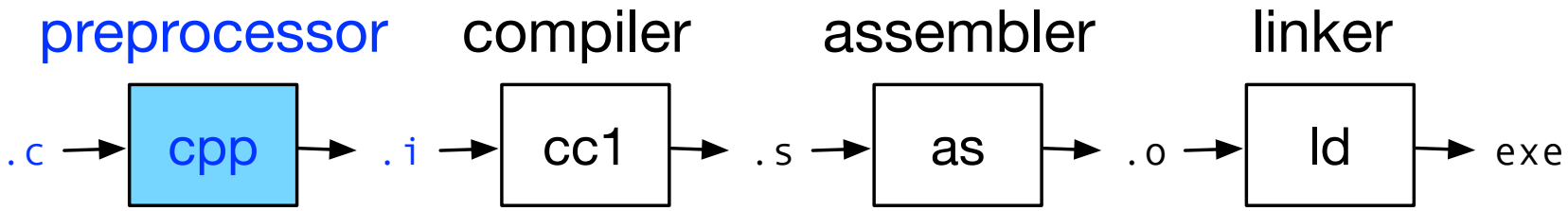
- C code first gets compiled into assembly code
- Assembly code is then converted into machine code

Even Simpler Program

- A simple C program: return47.c

```
#define FOURTYSEVEN 47
int main(void) {
  return FOURTYSEVEN;
}
```

Preprocessor

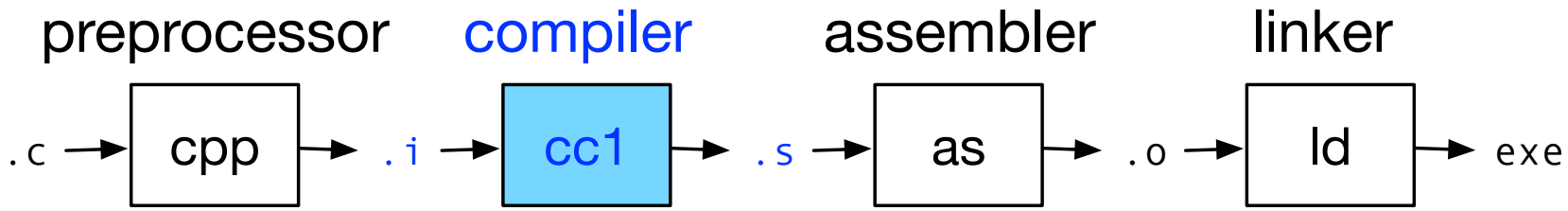


- Resolves constants (#define)
- Adds additional source code (#include)
- Handles other directives like #ifdef / #endif

- Example

```
linux> gcc -Og -E return47.c
[...]
int main(void) {
  return 47;
}
```

Compiler

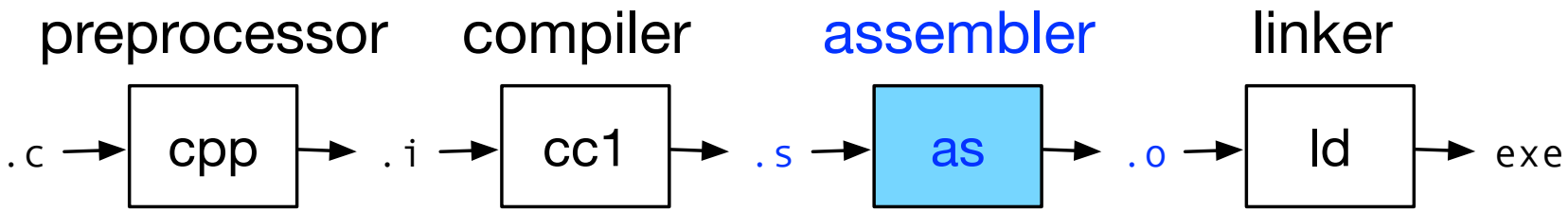


- Compilation into assembly code

- Example

```
linux> gcc -Og -S return47.c
linux> cat return47.s
[...]
main:
        movl    $47, %eax
        ret
```

Assembler

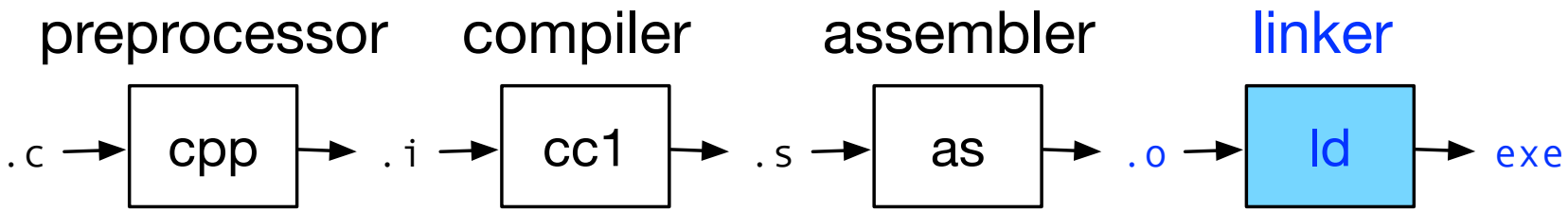


- Conversion into machine code

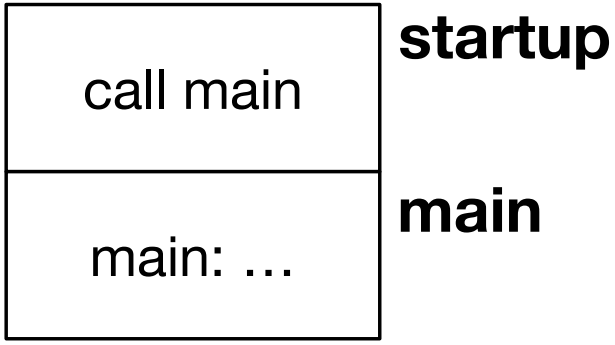
- Example

```
linux> gcc -Og -c return47.c
linux> objdump -d return47.o
[...]
0000000000000000 <main>:
   0:         b8 2f 00 00 00                mov    $0x2f,%eax
   5:         c3                            retq
```

Linker



- Adds start-up code
- May combine multiple object files



- Example

```
linux> gcc -Og return47.c
linux> ./a.out
linux> echo $?
47
```

loops

Simple Program with For Loop

```
int main(void) {
  int sum = 0;
  for(int i=0;i<100;i++) {
    sum += i;
  }
  return 0;
}
```

Assembly Code


```
main:
        movl        $0, %eax
        jmp         .L2
.L3:
        addl        $1, %eax
.L2:
        cmpl        $99, %eax
        jle         .L3
        movl        $0, %eax
        ret
```

Assembly Code


```
main:
        movl    $0, %eax
        jmp     .L2
.L3:
        addl    $1, %eax
.L2:
        cmpl    $99, %eax
        jle     .L3
        movl    $0, %eax
        ret
```

- **Wait!** --- where is the sum computed?

Assembly Code


```
main:
        movl    $0, %eax
        jmp     .L2
.L3:
        addl    $1, %eax
.L2:
        cmpl    $99, %eax
        jle     .L3
        movl    $0, %eax
        ret
```

- **Wait!** --- where is the sum computed?
- Removed by optimizations in compiler (sum is never used)
- Compiling with -O9 would also remove loop

Use Sum as Return Value

```
int main(void) {
  int sum = 0;
  for(int i=0;i<100;i++) {
    sum += i;
  }
  return sum;
}
```

Assembly Code


```
main:
.LFB0:
        movl    $0, %edx
        movl    $0, %eax
        jmp     .L2
.L3:
        addl    %edx, %eax
        addl    $1, %edx
.L2:
        cmpl    $99, %edx
        jle     .L3
        rep ret
```

- Now sum is computed in register %eax (return value)

```
hello world
```

Source Code

```
#include <stdlib.h>
#include <stdio.h>

int main(void) {
  printf("Hello world!\n");
  return EXIT_SUCCESS;
}
```

Assembly Code

- Compiled into:

```
        .LC0:
                .string     "Hello world!"
                .text
                .globl      main
                .type       main, @function
        main:
                subq        $8, %rsp
                movl        $.LC0, %edi
                call        puts
                movl        $0, %eax
                addq        $8, %rsp
                ret
```

- Calls the function "puts"

Machine Code (Disassembled)

- Object code

```
linux> objdump -t hello-world.o
[...]
0000000000000000 g     F .text          0000000000000018 main
0000000000000000         *UND*          0000000000000000 puts
```

- Function "puts" is labeled as undefined (*UND*)

- Linker resolves this