CS5600: Computer Systems

Fall 2017

Goals

- Study some of the fundamental problems and solutions of OS
- Work on a small toy OS, PintOS
  - Extend functionality
  - Add functionality
- Project based course

Course Setup

- Lectures, notes and readings provide an exposition of the problem(s) and their solutions
- Projects rely on you to apply (as-is, modified, or your own) solution to PintOS
- Course staff treats students as professional developers

Course Evaluation

- 2 projects work individually
- 1 or 2 projects in groups of 3
- You are professional developers
  - Clear and Clean and documented source code
  - Documentation for your solution
    - Design and reasons for your choice
    - Analysis (space, time)
    - Concurrency (starvation, liveness)

Hard Work

- There is a lot of work!
- We will expose some of the inner workings
  - what most classes up to know relied upon as “black box”
- Low lever (architecture, assembly)
- Interesting and hard problems
  - Concurrency, Garbage Collection etc.

Hard Work

- Assignments will take time and effort (2nd onwards)
  - understand PintOS code
  - some of the standard C libraries that you know are **not** available in PintOS (some close replacements exist)
  - work with some less that intuitive tools
  - “live on the command line”

Assumptions

- Medium level familiarity with C
  - structs, pointers, malloc, free etc.
  - See last Fall's class web site (http://www.ccs.neu.edu/home/skotthe/classes/cs5600/fall/2016/assignments.html)
    - Assignments 3 and 4
    - Labs 1 and 2
- Basic understanding of shell and OS
  - process, pids, pipes, files, directories etc.
- Basic understanding of linking loading and execution
  - object files, libs, linking, execution stack etc.

Logistics

- Class Web Site:
  - https://course.ccs.neu.edu/cs5600f17/
- Piazza
  - https://piazza.com/class/j72wxxlxk3h10o

Compile and Run

loop.c

```
int main(void) {
    int sum = 0;
    int i;

    for (i = 0; i < 10; i++){
        sum = sum + i;
    }
    return sum;
}
```

1. Compile
   gcc -O0 loop.c

2. Run
   ./a.out

Compile

loop.c

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int main(void) {
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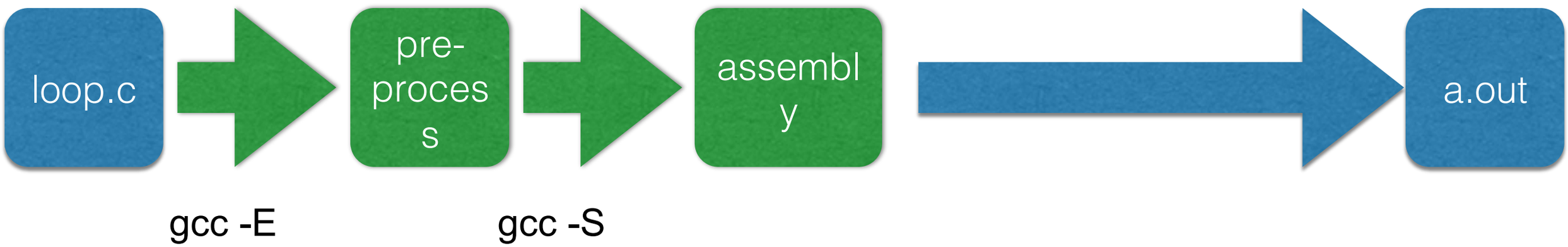

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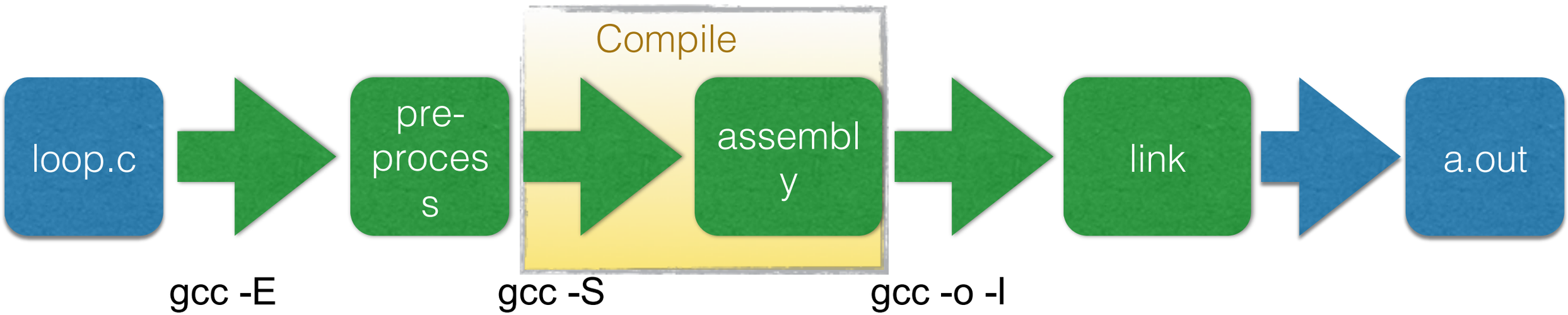

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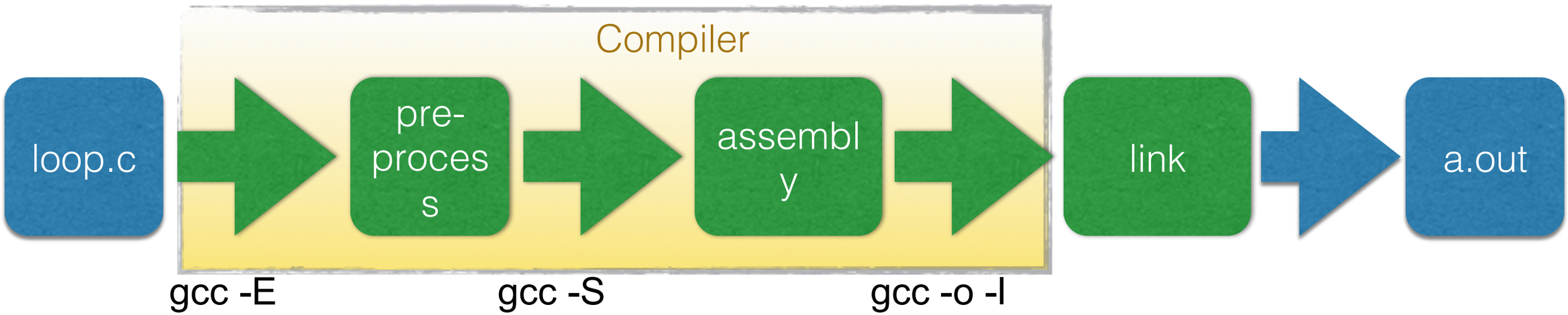


gcc -O0 -E loop.c

loop.c

```
int main(void) {
    int sum = 0;
    int i;

    for (i = 0; i < 10; i++){
        sum = sum + i;
    }
    return sum;
}
```

```
# 1 "loop.c"
# 1 "<built-in>"
# 1 "<command-line>"
# 1 "/usr/include/stdc-predef.h" 1 3 4
# 1 "<command-line>" 2
# 1 "loop.c"
int main(void) {
    int sum = 0;
    int i;

    for (i = 0; i < 10; i++){
        sum = sum + i;
    }
    return sum;
}
```

gcc -O0 -S loop.c

loop.c

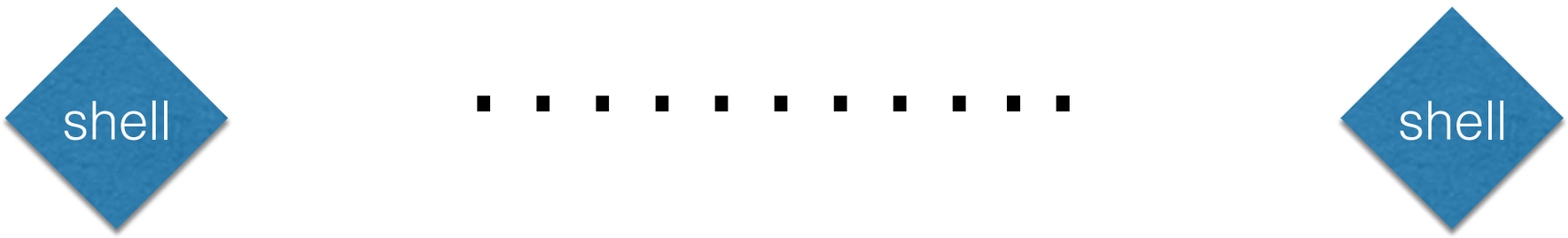
```
int main(void) {
    int sum = 0;
    int i;

    for (i = 0; i < 10; i++){
        sum = sum + i;
    }
    return sum;
}
```

With some debugging instructions removed

```
        .file "loop.c"
        .text
        .globl     main
        .type main, @function
main:
.LFB0:
        pushl %ebp
        movl  %esp, %ebp
        subl  $16, %esp
        movl  $0, -4(%ebp)
        movl  $0, -8(%ebp)
        jmp   .L2
.L3:
        movl  -8(%ebp), %eax
        addl  %eax, -4(%ebp)
        addl  $1, -8(%ebp)
.L2:
        cmpl  $9, -8(%ebp)
        jle   .L3
        movl  -4(%ebp), %eax
        leave
        ret
.LFE0:
        .size main, .-main
        .ident     "GCC: (Debian 4.9.2-10) 4.9.2"
        .section   .note.GNU-stack,"",@progbits
```

Run



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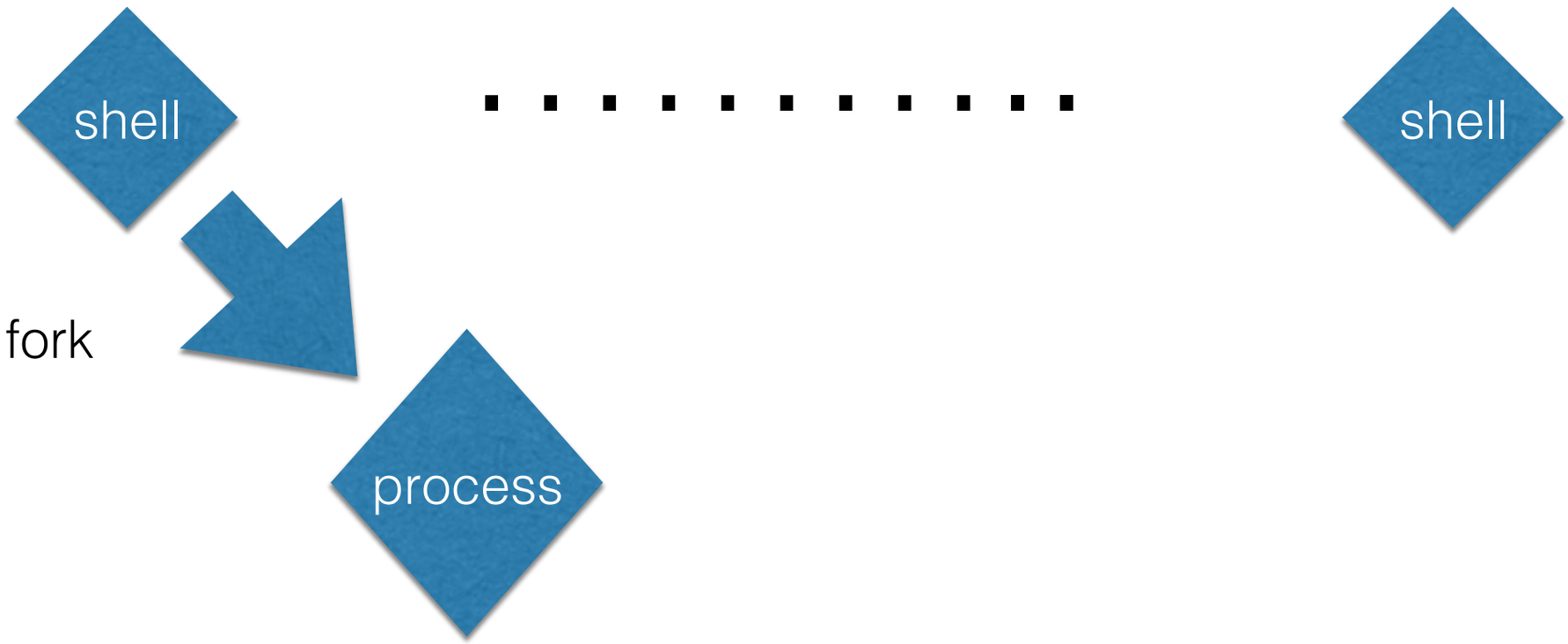

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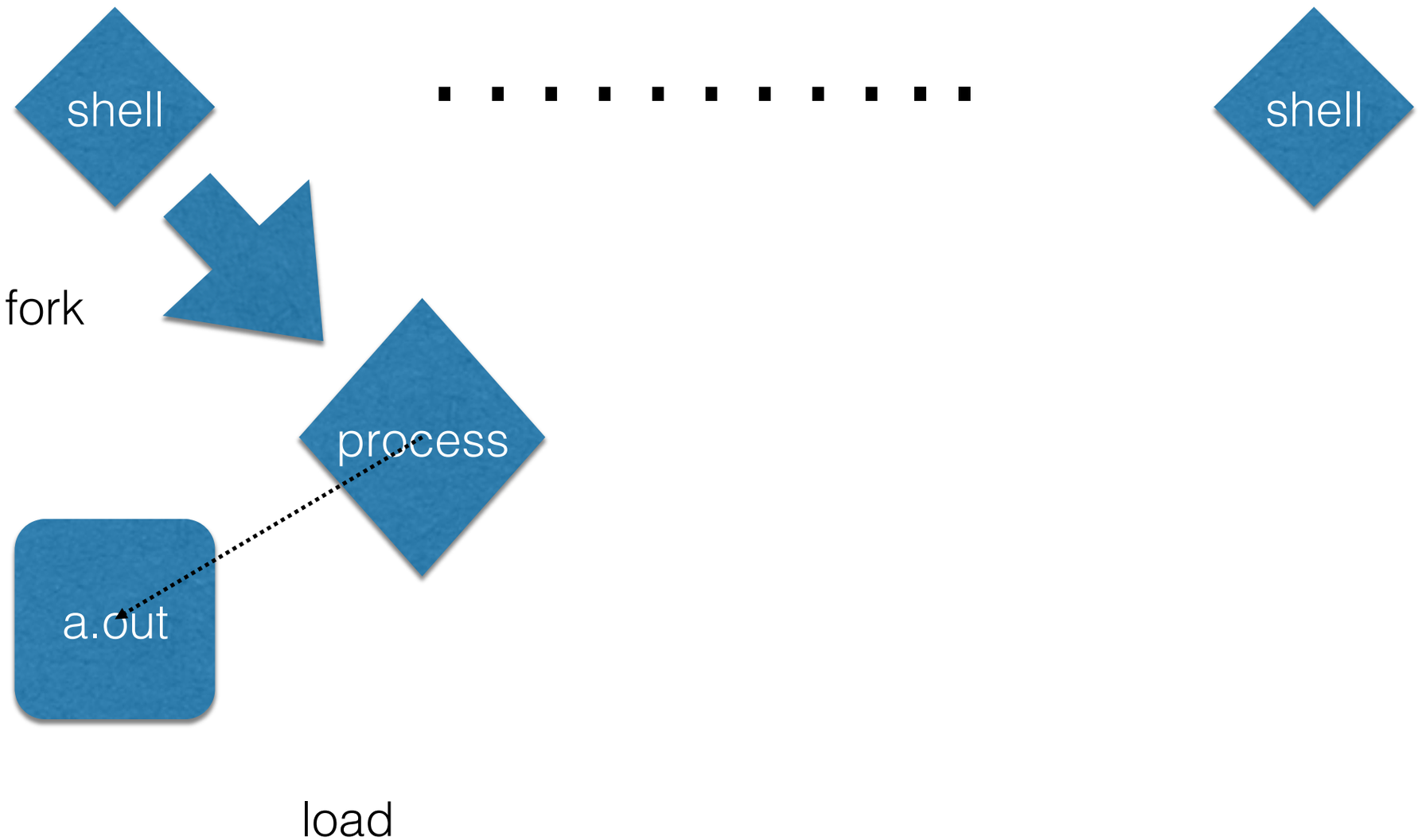
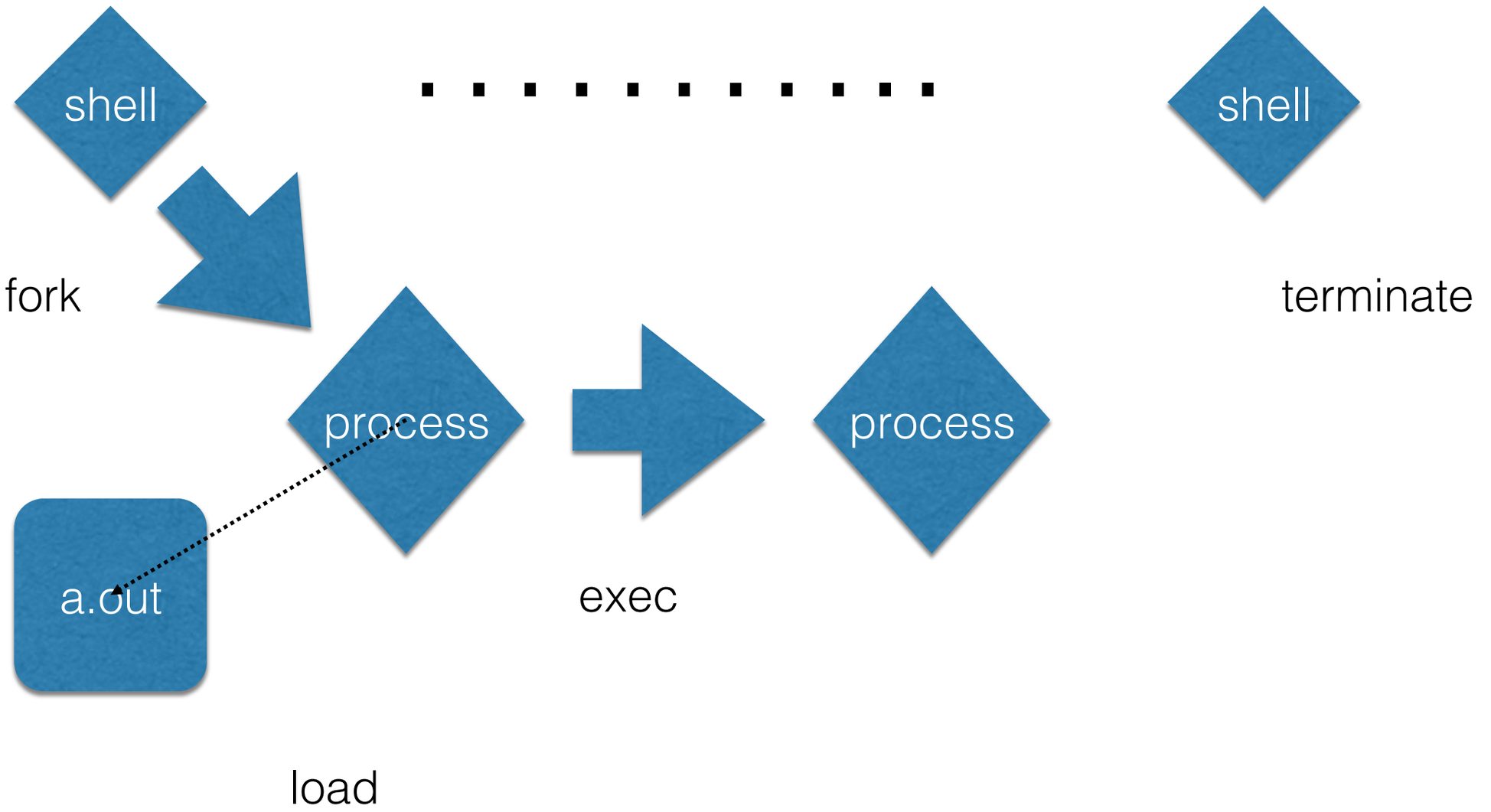
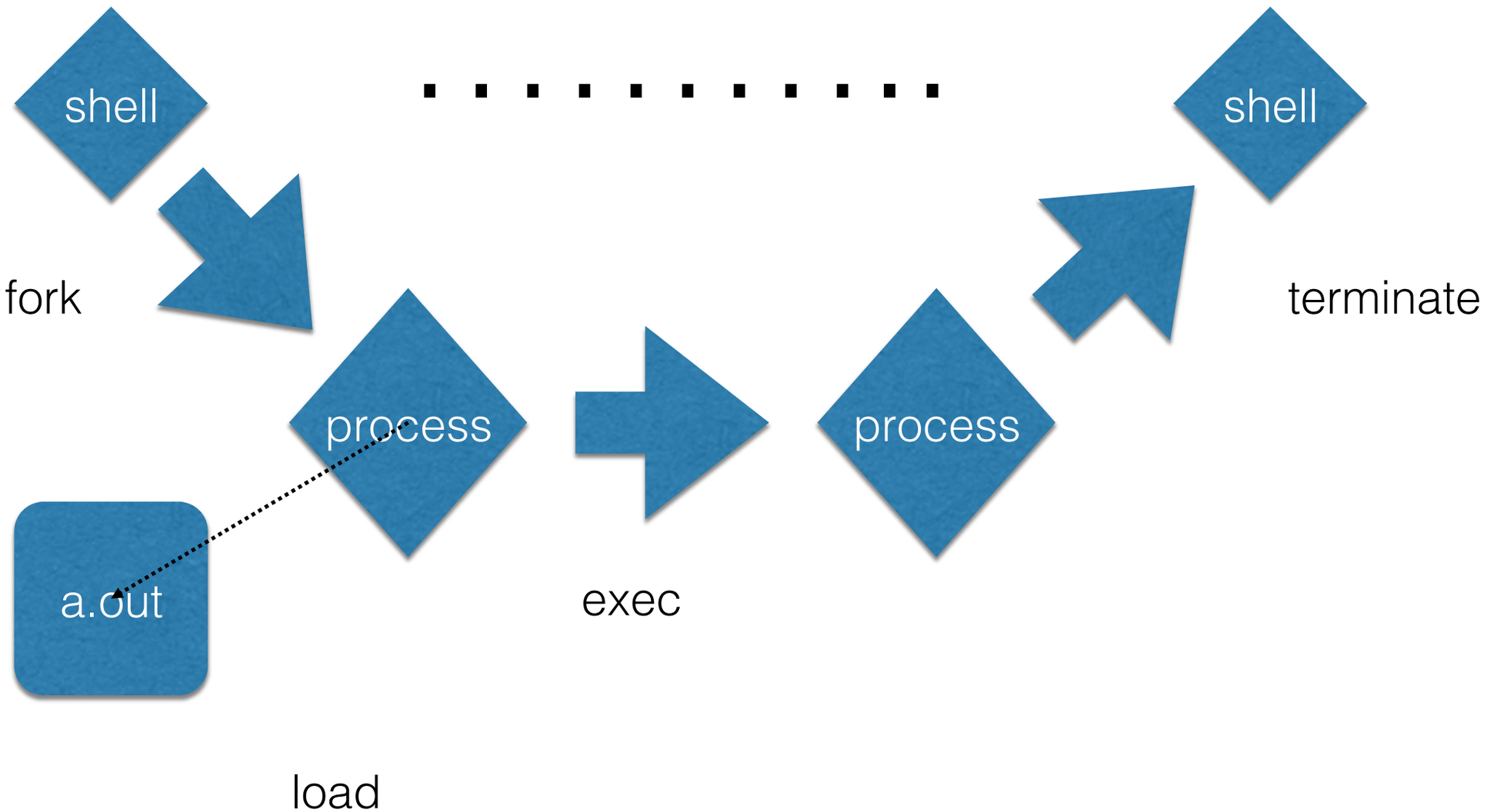


Run



Run



Run

loop.c

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1. Run
   ./a.out

What type of a file is a.out?

Run

loop.c

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    for (i = 0; i < 10; i++){
        sum = sum + i;
    }
    return sum;
}
```

1. Run
   ./a.out

What type of a file is a.out?

```
therapon@vdebian:~/Lectures/01$ file a.out

a.out: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV), dynamically linked, interpreter /lib/ld-linux.so.2, for GNU/Linux 2.6.32,
BuildID[sha1]=f725959a7360fc04d6cc7190ccc4a0428946c217, not stripped
```

ELF

- **E**xecutable and **L**inkable **F**ormat
- A way to organize the information in the file
- One header and data
- Data is made up of
  - Program header table, describes 0 or more segments
  - Section header table, describe 0 or more sections
  - Data referred to by entries in the program and section header tables

ELF

```
therapon@vdebian:~/Lectures/01$ readelf -h a.out
ELF Header:
  Magic:   7f 45 4c 46 01 01 01 00 00 00 00 00 00 00 00 00
  Class:                             ELF32
  Data:                              2's complement, little endian
  Version:                           1 (current)
  OS/ABI:                            UNIX - System V
  ABI Version:                       0
  Type:                              EXEC (Executable file)
  Machine:                           Intel 80386
  Version:                           0x1
  Entry point address:               0x80482d0
  Start of program headers:          52 (bytes into file)
  Start of section headers:          3616 (bytes into file)
  Flags:                             0x0
  Size of this header:               52 (bytes)
  Size of program headers:           32 (bytes)
  Number of program headers:         8
  Size of section headers:           40 (bytes)
  Number of section headers:         30
  Section header string table index: 27
```

The “black boxes”

- How do we go from file to running program?
- How do we manage a running program?
  - stack, access to files, devices, memory, etc.
- How do we provide isolation and communication between programs?
  - inter-process communication, privileged access to devices
- How do we get the OS to run and who manages the OS while running?

It’s all 0s and 1s

- We will see
  - how a machine boots up
  - how processes are created and managed
  - how code is loaded, executed and managed (memory management)
  - access to hardware features (shared, privileged etc)
  - filesystem