The Processes Abstraction (ch. 4)

Operating Systems

Based on: Three Easy Pieces by Arpaci-Dusseaux

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The Process

A running program

- Lots of processes seemingly running at the same time
- The challenge:
  - Few physical CPUs, illusion of many CPUs

The Process

- **Virtualizing** the CPU
  - Running one process, stopping it, running another, and so forth
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- **Context switch**
  - Low-level mechanism
  - Stop running one program and start running another
- **Scheduling policy**
  - Algorithm to decide which process should run next
  - By history, workload, performance

Context switch example (xv6-riscv64)

```
swtch:
        sd ra, 0(a0)
        sd sp, 8(a0)
        sd s0, 16(a0)
        sd s1, 24(a0)
        sd s2, 32(a0)
        sd s3, 40(a0)
        sd s4, 48(a0)
        sd s5, 56(a0)
        sd s6, 64(a0)
        sd s7, 72(a0)
        sd s8, 80(a0)
        sd s9, 88(a0)
        sd s10, 96(a0)
        sd s11, 104(a0)
```

```
        ld ra, 0(a1)
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        ret
```

Time and Space Sharing

- **Time sharing**
  - Resource used for a little while by one entity, then a little while by another, and so forth
  - e.g., CPU
- **Space sharing**
  - Resource is divided (in space) among those who wish to use it
  - e.g., memory, disk

Process vs. Program

- **Program**: static code and static data
- **Process**: dynamic instance of the program

- Multiple processes of the same program can exist

What constitutes a process?

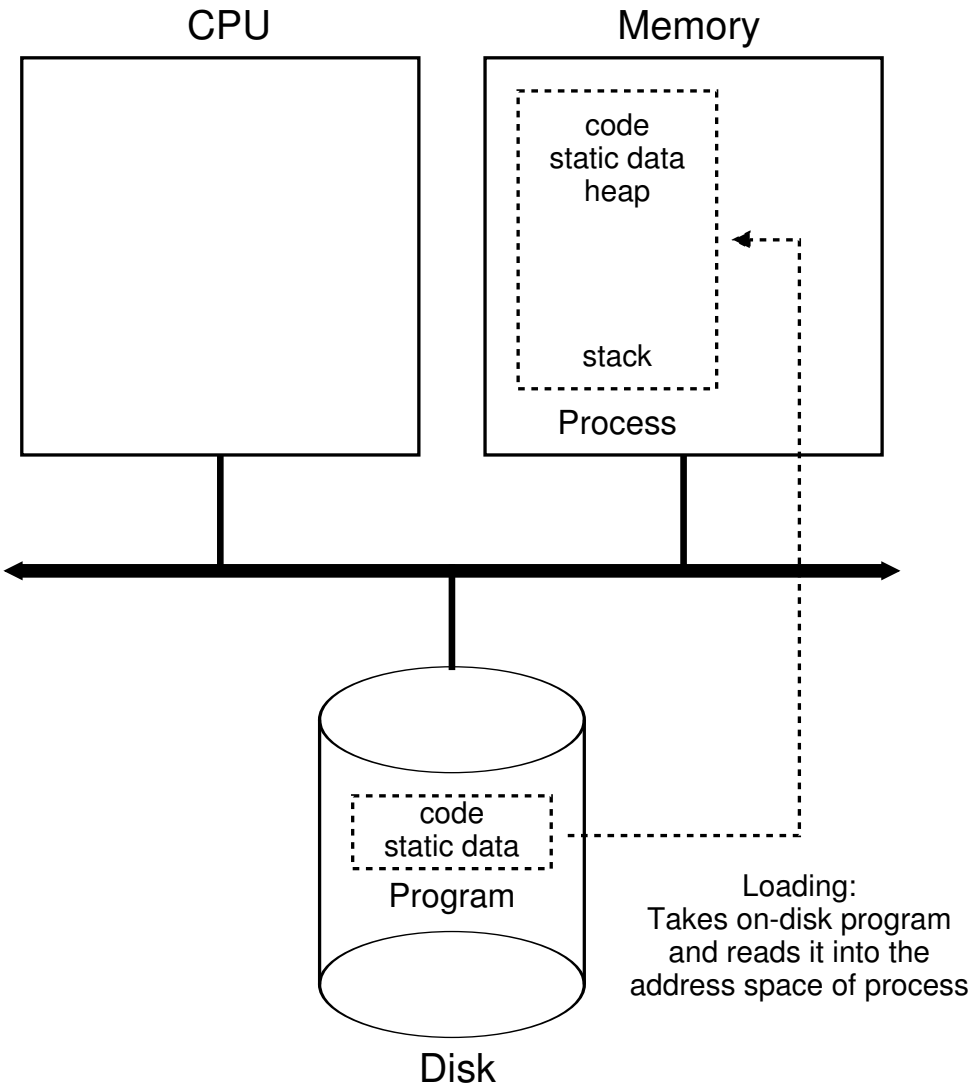
- Memory (**address space**)
  - Instructions (program code)
  - Data (static and dynamic)
  - `cat /proc/<PID>/maps`
- Registers
  - Program counter (PC)
  - Stack pointer
  - etc.
- I/O information
  - e.g., open files
  - `cat /proc/<PID>/fdinfo/*`

Process Creation

- Unix likes OSes: A process is a replica of a currently existing process.
  - There is a way to load an executable file into an existing process.
- Non-Unix like OSes: A process is created with information from an exe file.

Either way, the first process is created by the OS on initialization.

Executable Loading



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- Allocate the **heap**
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  - Request space by calling `malloc`, free it by `free`
- Start program at entry point (NOT necessarily `main()`)
  - Transfer control of CPU to the newly-created process

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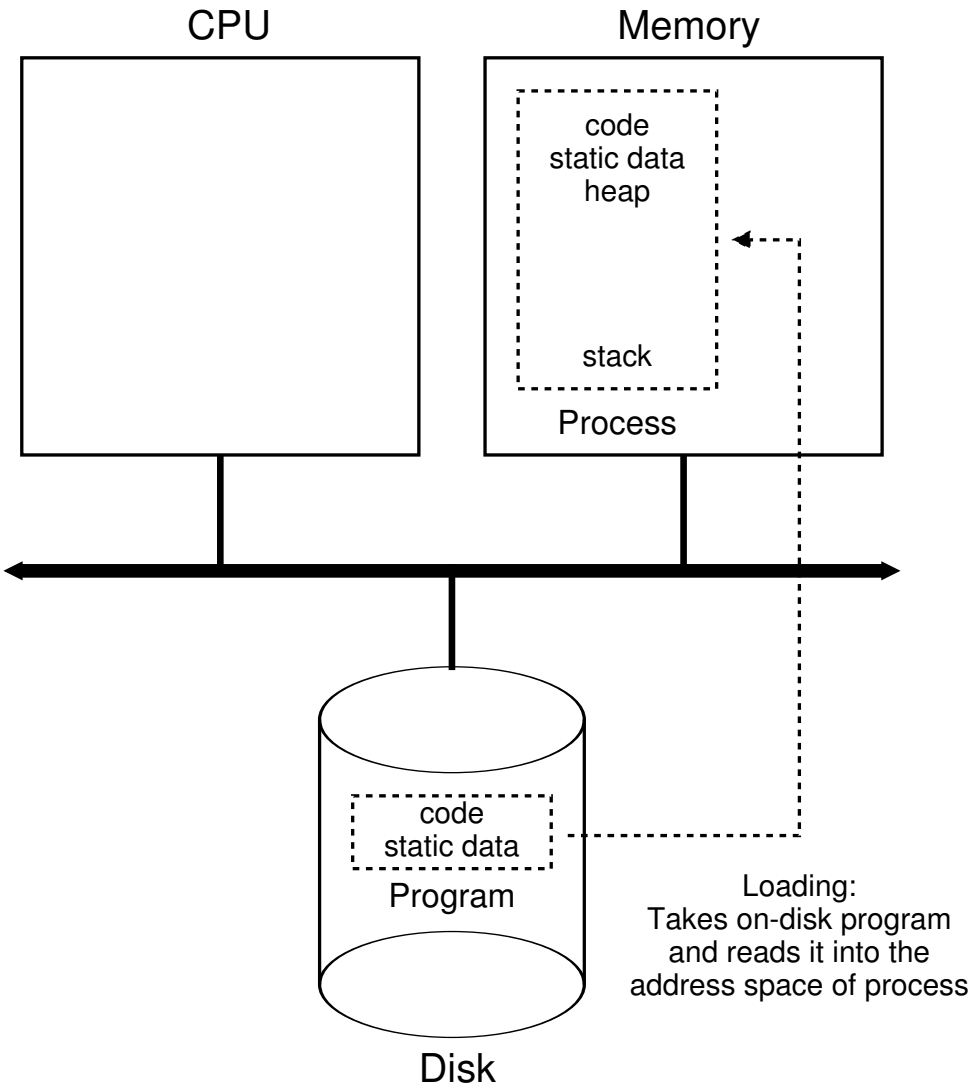
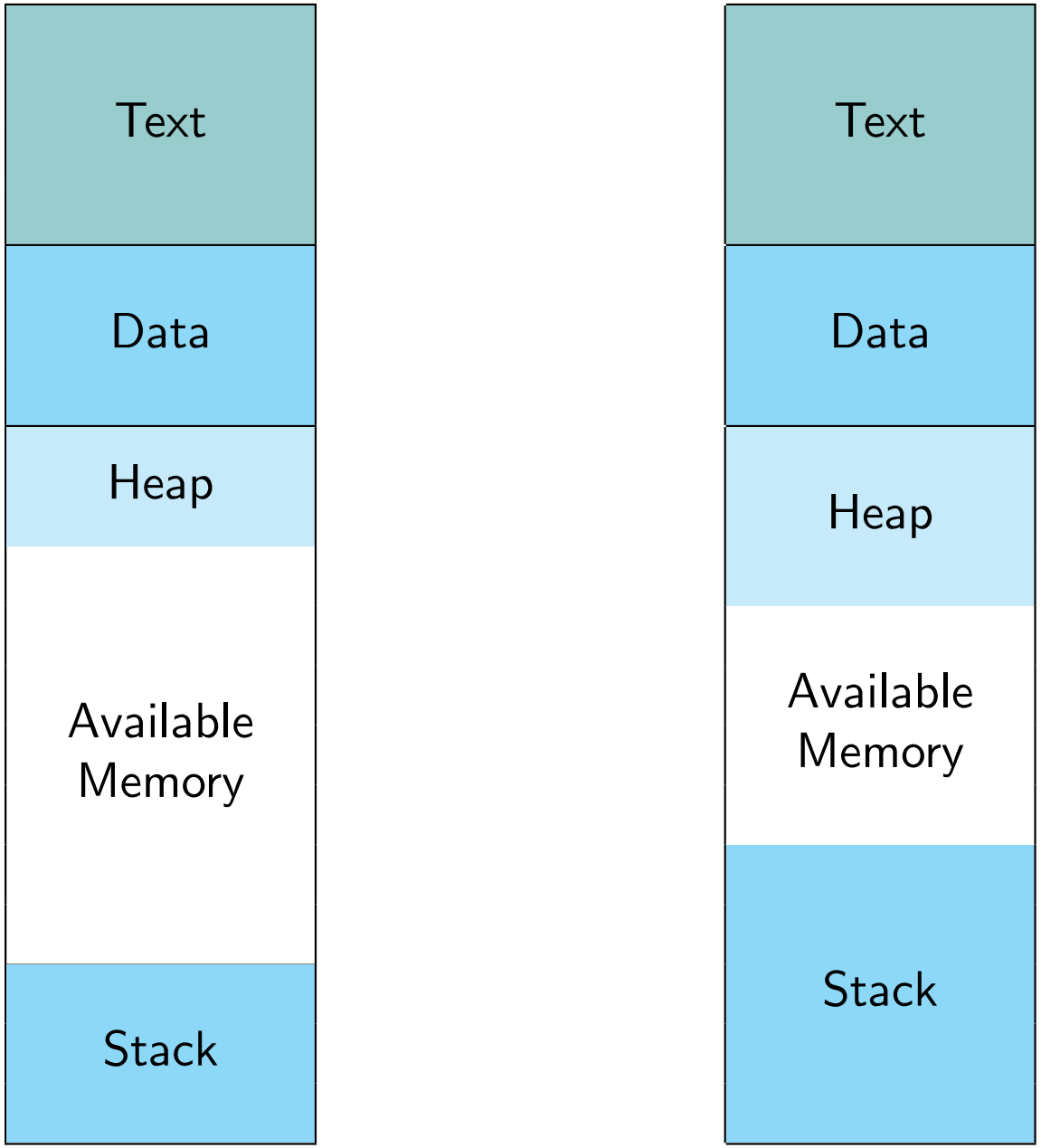


Two Processes for One Program (Virt Mem View)



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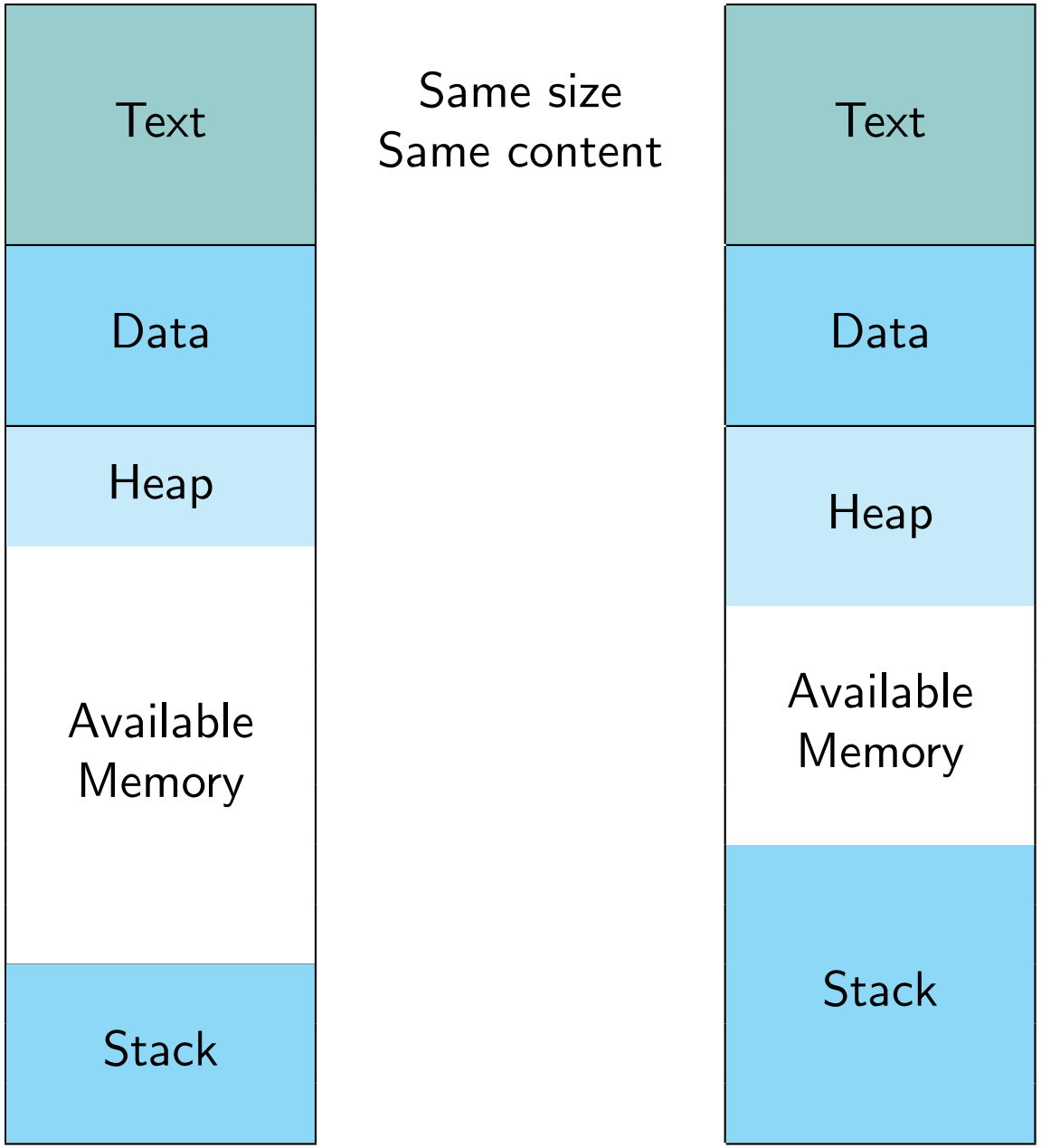

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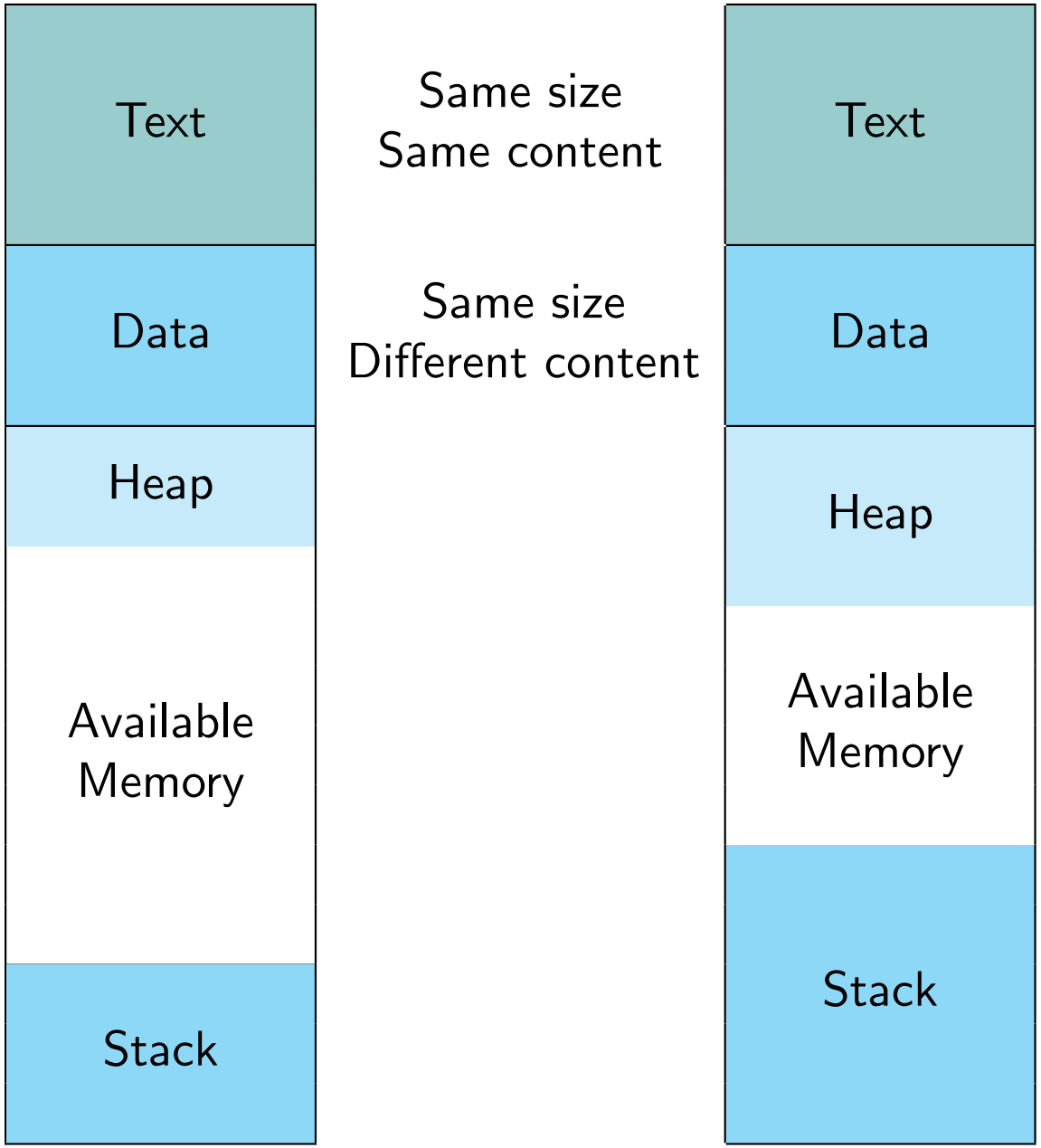

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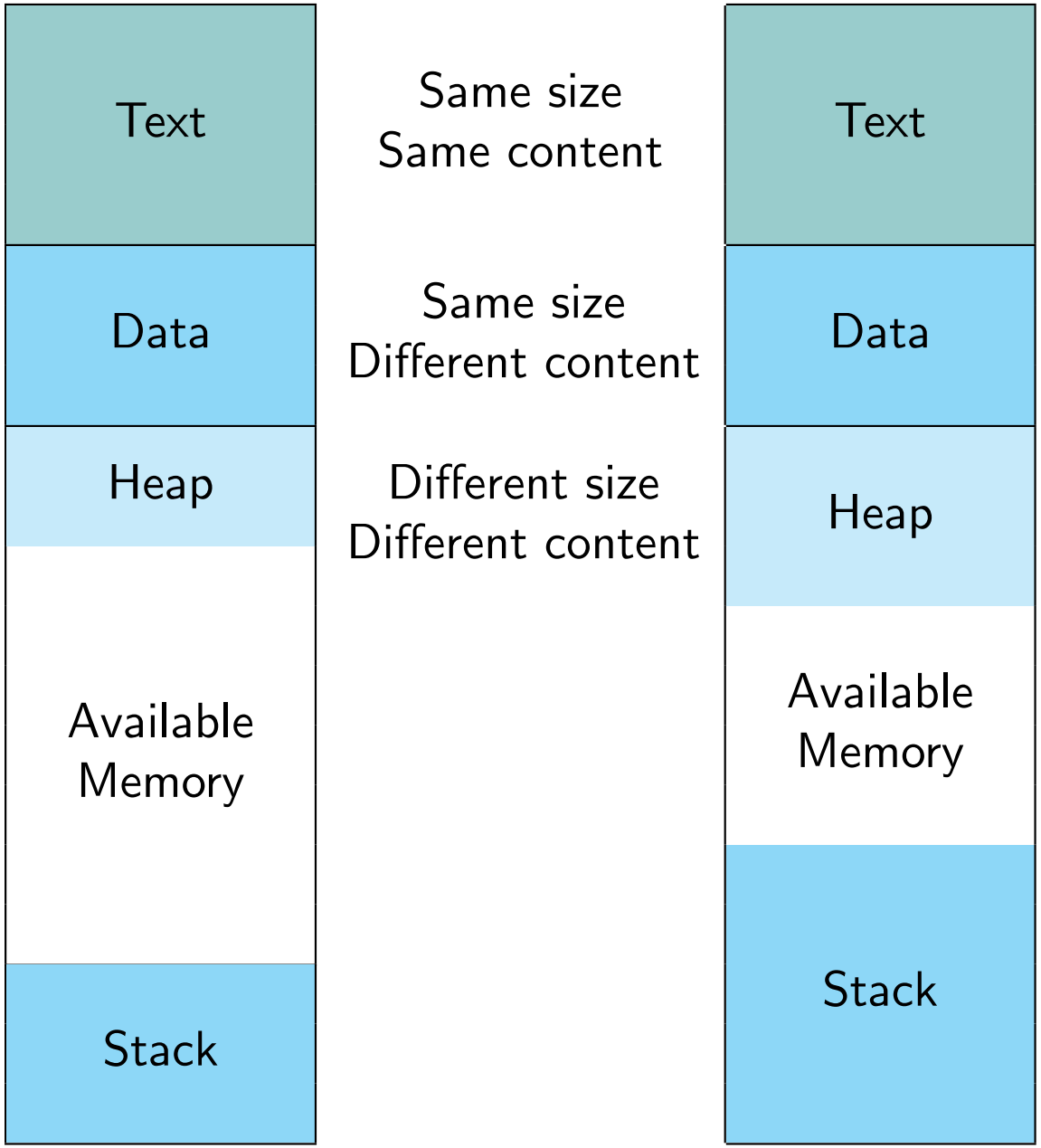

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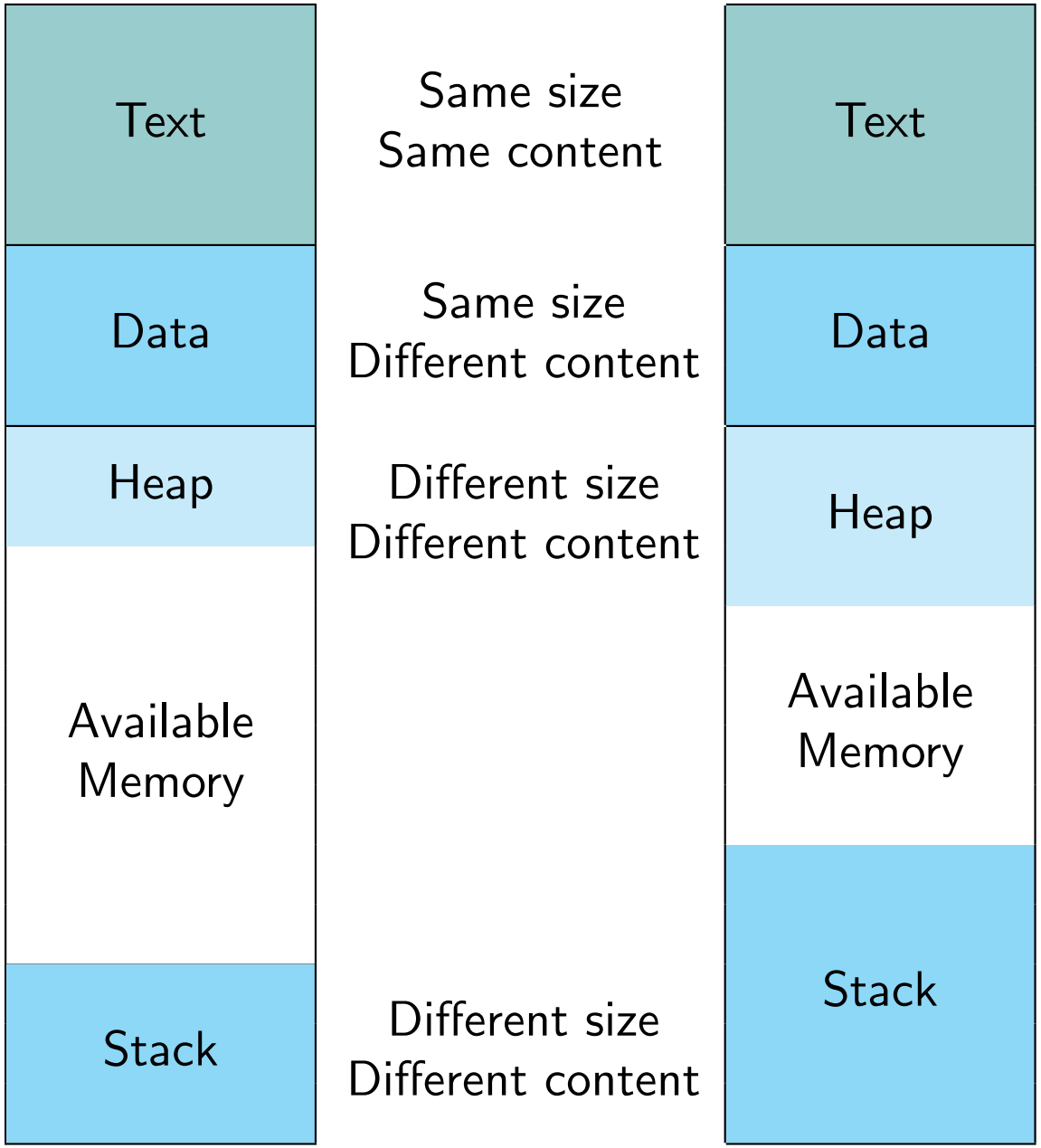

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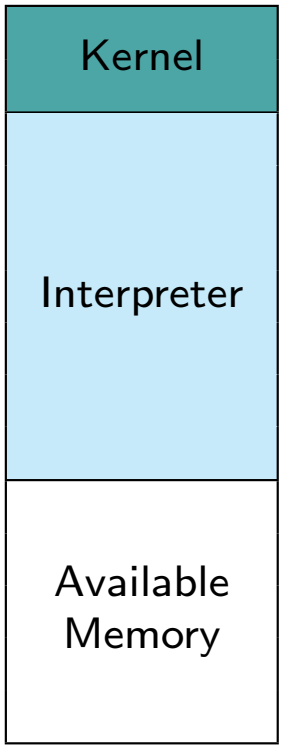

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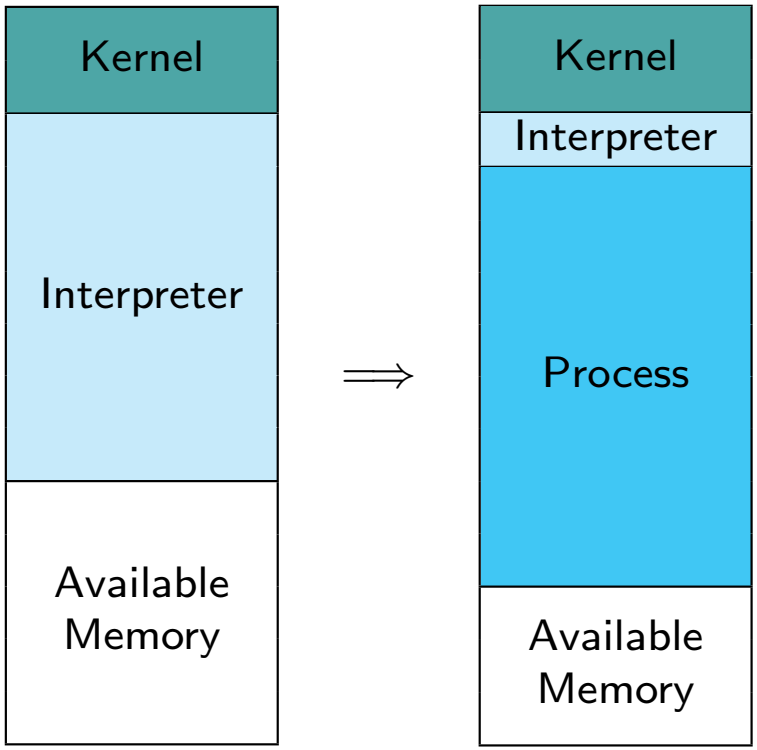
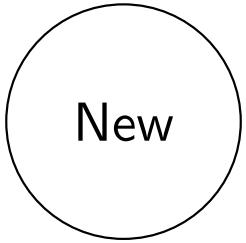


Process Life Cycle - Single Tasking



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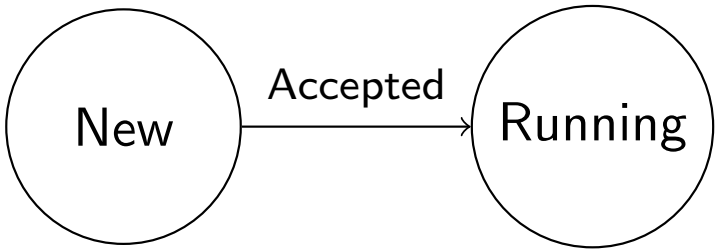

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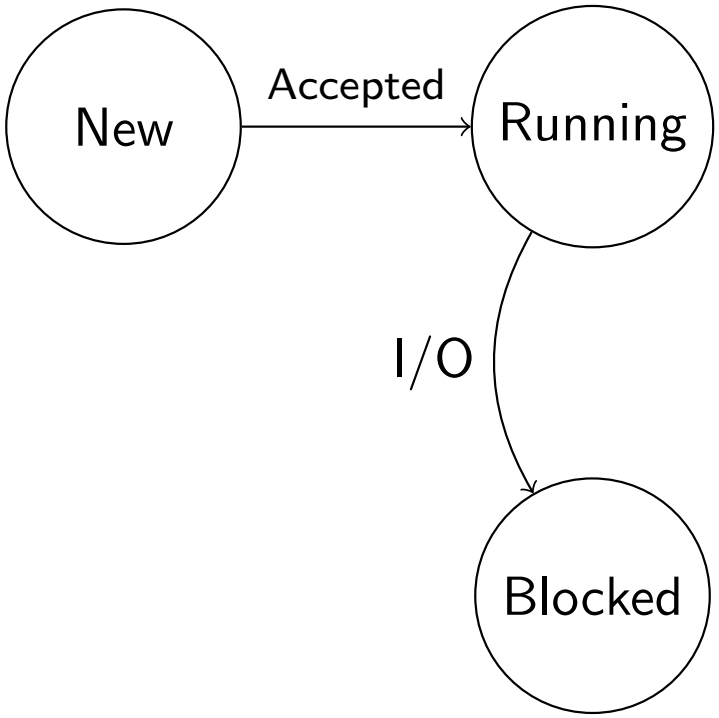

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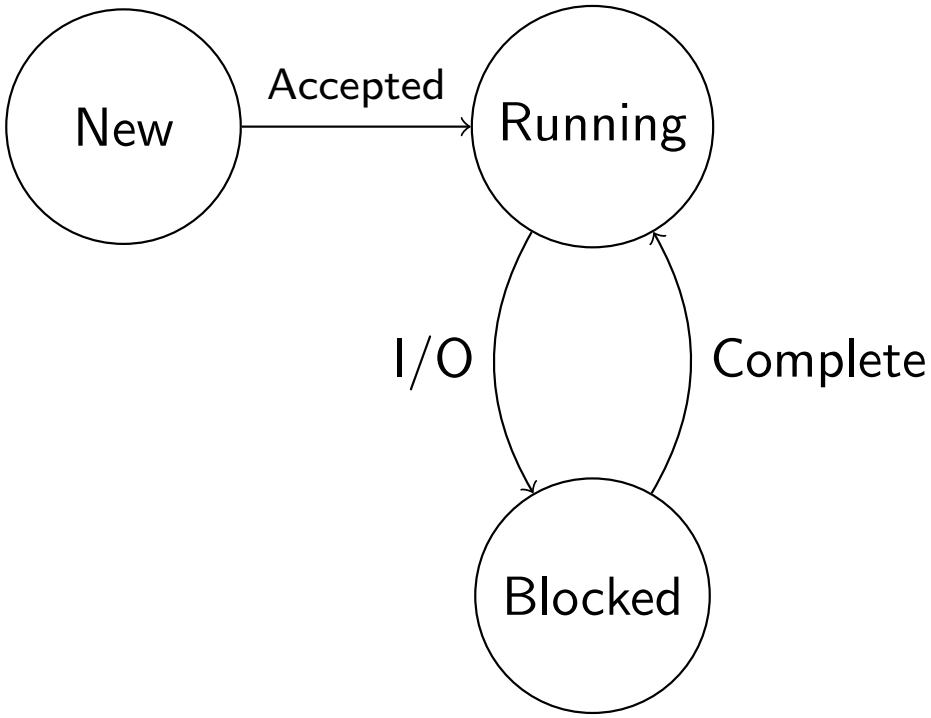

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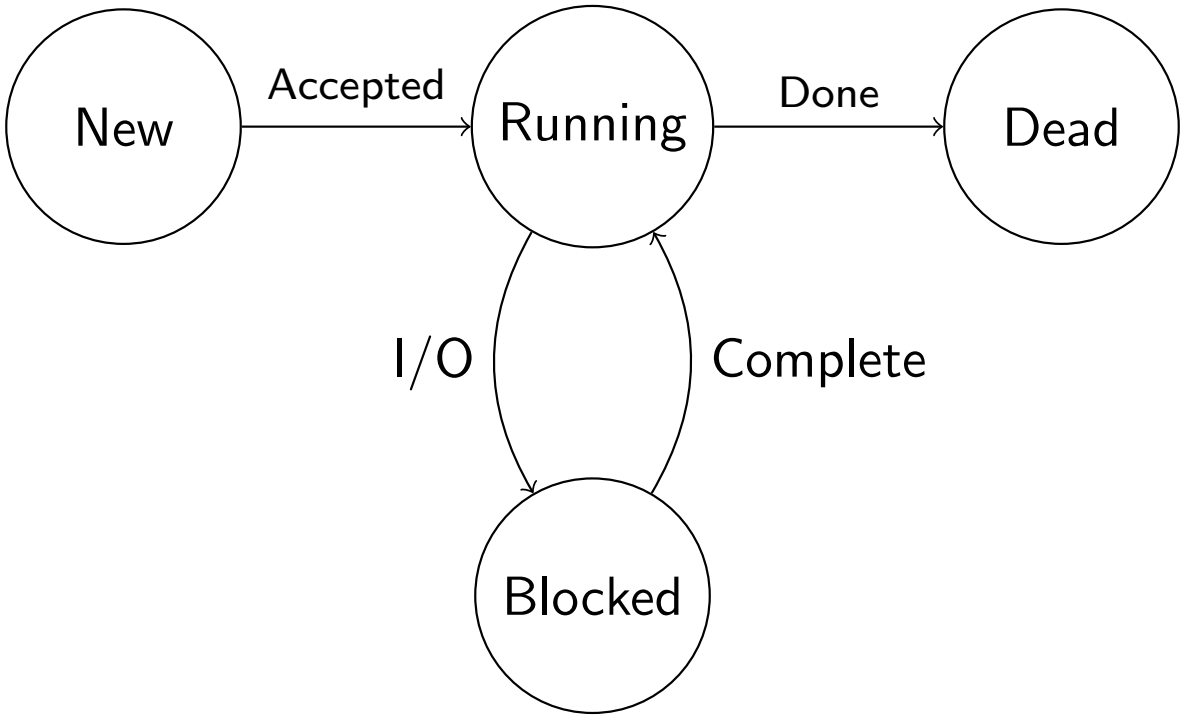

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- Modern operating systems: **multi-tasking**
  - Multiple processes co-exist
  - **Cooperative** multi-tasking: `yield`
  - **Preemptive** multi-tasking: **interrupts**

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- Modern operating systems: **multi-tasking**
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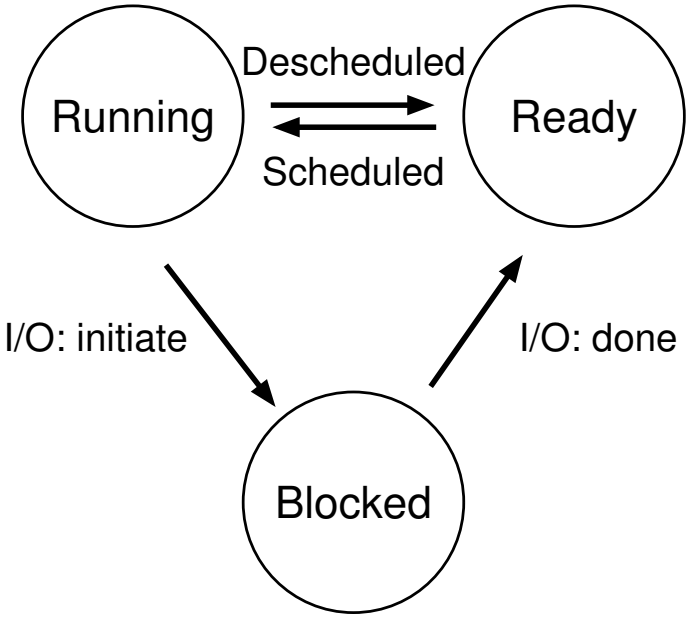
  - **Cooperative** multi-tasking: `yield`
  - **Preemptive** multi-tasking: **interrupts**
- A process can be **ready** to run, but not running
  - OS schedules a process to run for a while, then deschedules it and picks another process, and so forth
  - A new state: **ready**

Process States

- **Running**: executing on CPU
- **Ready**: ready to run, waiting to be scheduled
- **Blocked**: suspended, waiting for some event



Process States - Example I

Time	Process 0	Process 1	Notes
1	Running	Ready	
2	Running	Ready	
3	Running	Ready	
4	Running	Ready	Process 0 done
5	-	Running	
6	-	Running	
7	-	Running	
8	-	Running	Process 1 done

Process States - Example II

Time	Process 0	Process 1	Notes
1	Running	Ready	
2	Running	Ready	
3	Running	Ready	0 initiates I/O
4	Blocked	Running	0 is blocked
5	Blocked	Running	so 1 runs
6	Blocked	Running	
7	Ready	Running	I/O done
8	Ready	Running	Process 1 done
9	Running	-	
10	Running	-	Process 0 done

Data Structures

- OS maintains a data structure of active processes
  - The **process table**
  - Limited size - `cat /proc/sys/kernel/threads-max`

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- Process Control Block (**PCB**):
  - Process identifier (**PID**)
  - State
  - Related processes (parent)
  - CPU context, e.g., registers (saved when suspended)
  - Memory locations
  - Open files

Summary (Process Abstraction)

- **Process**: OS abstraction of a running program
- Can be described by:
  - **Address space**
  - CPU registers (inc. **program counter** & **stack pointer**)
  - I/O information (e.g., open files)
- **Process state**: running, ready to run, blocked.
  - transition by different events
- **Process list**: information about all processes in the system
  - **Process control block**: a structure with information about a specific process