K22 – Operating Systems: Design Principles and Internals

Fall 2026 @dit (α.μ. mod 2 = 1)

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Lecture 07

References: Similar OS courses @Columbia, @Stanford, @UC San Diego, @Brown, @di (previous years); and textbooks: Operating Systems: Three Easy Pieces, Operating Systems: Principles and Practice, Operating System Concepts, Linux Kernel Development, Understanding the Linux Kernel

Overview

- We'll start from hardware and follow a question-oriented approach
  - ~~Intro [Q: What is an OS?]~~
  - ~~Events [Q: When does the OS run?]~~
  - ~~Runtime [Q: How does a program look like in memory?]~~
  - ~~Processes [Q: What is a process?]~~
  - IPC [Q: How do processes communicate?]
  - Threads [Q: What is a thread?]
  - Synchronization [Q: What goes wrong w/o synchronization?]
  - Time Management [Q: What is scheduling?]
  - Memory Management [Q: What is virtual memory?]
  - Files [Q: What is a file descriptor?]
  - Storage Management [Q: How do we allocate disk space to files?]

* Basic (H/W & S/W)
* Abstractions
* Primitives
* Mechanisms

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Overview

- InterProcess Communication (IPC)
  - **Q1**: How do processes communicate with each other?
  - **Q2**: What are the most common asynchronous POSIX IPC mechanisms?
  - **Q3**: What are the most common synchronous POSIX IPC mechanisms?
  - **Q4**: How does a General Protection Fault (GPF) lead to the notorious POSIX SIGSEGV?

    ...

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- Asynchronous: The recipient cannot be assumed "prepared"
- Synchronous: The recipient can be assumed "prepared"

Asynchronous and synchronous IPC

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> Synchronous IPC: The recipient process is waiting for a message to be delivered to it

- Example: POSIX pipes, POSIX shared memory

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    - Signals that cannot be "handled": SIGKILL(9), SIGSTOP(19) [see this]

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> See int sigaltstack(stack_t ***ss**, stack_t ***oss**)

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- Signals generated by some action attributable to a particular thread shall be delivered to the thread that caused the signal to be generated
- Signals that are generated in association with a process ID or a process group ID or an asynchronous event shall be delivered to that process or process group

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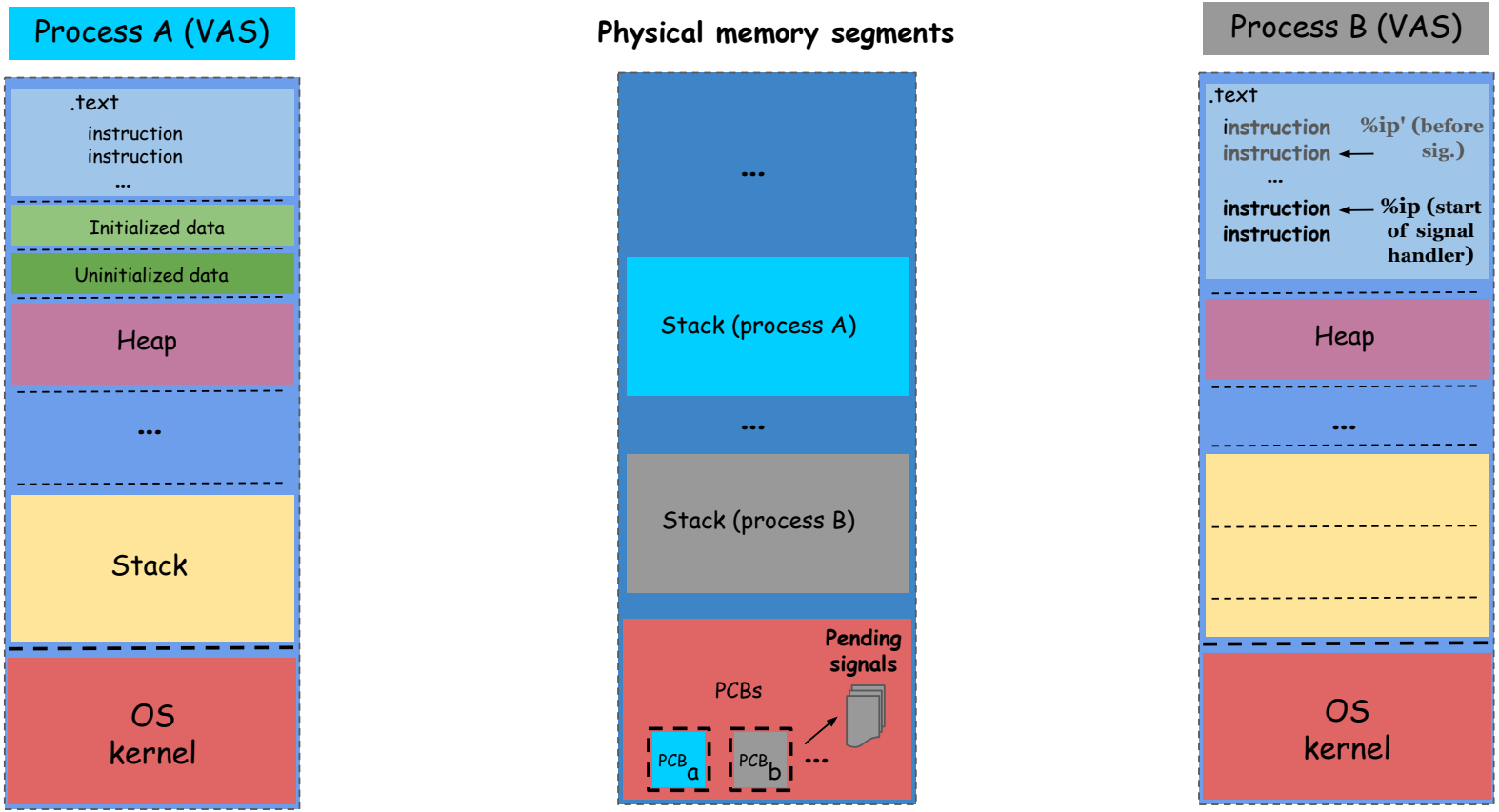
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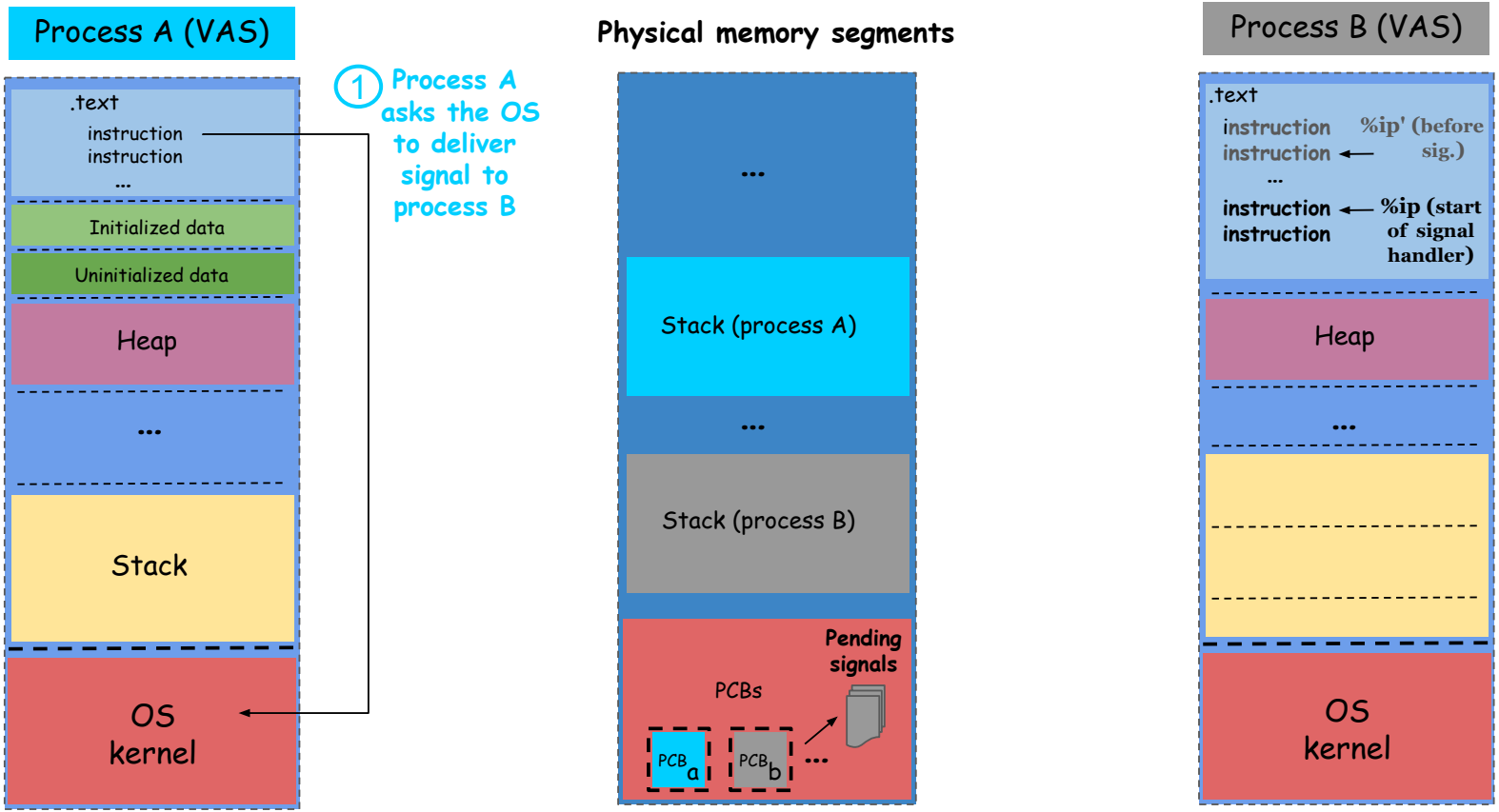
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- If the action associated with a blocked signal is anything other than to ignore the signal, and if that signal is generated for the thread, the signal shall remain pending until it is either (i) unblocked, or (ii) selected and returned by a call to sigwait() function, or (iii) the action associated with it is set to ignore the signal

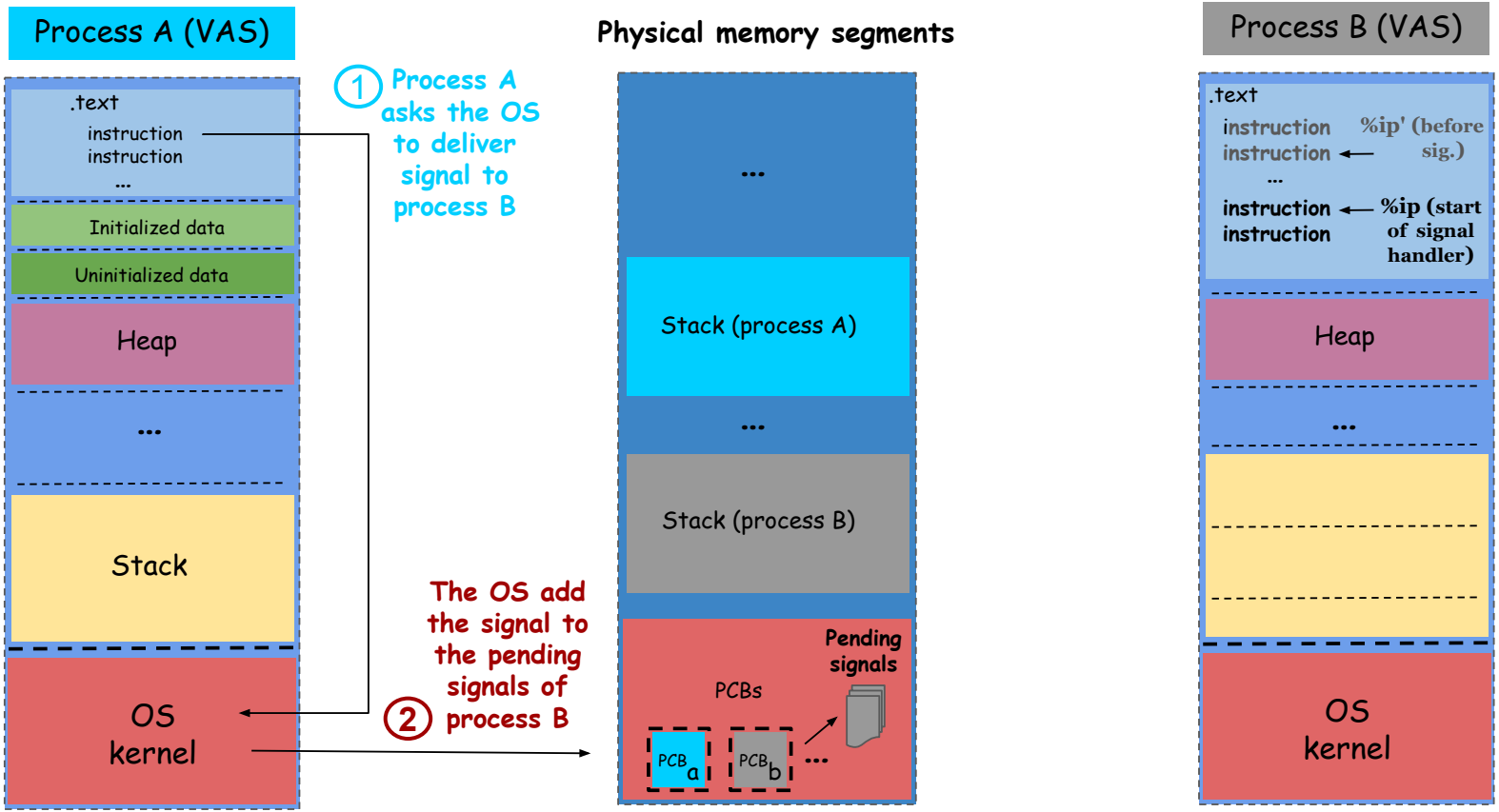
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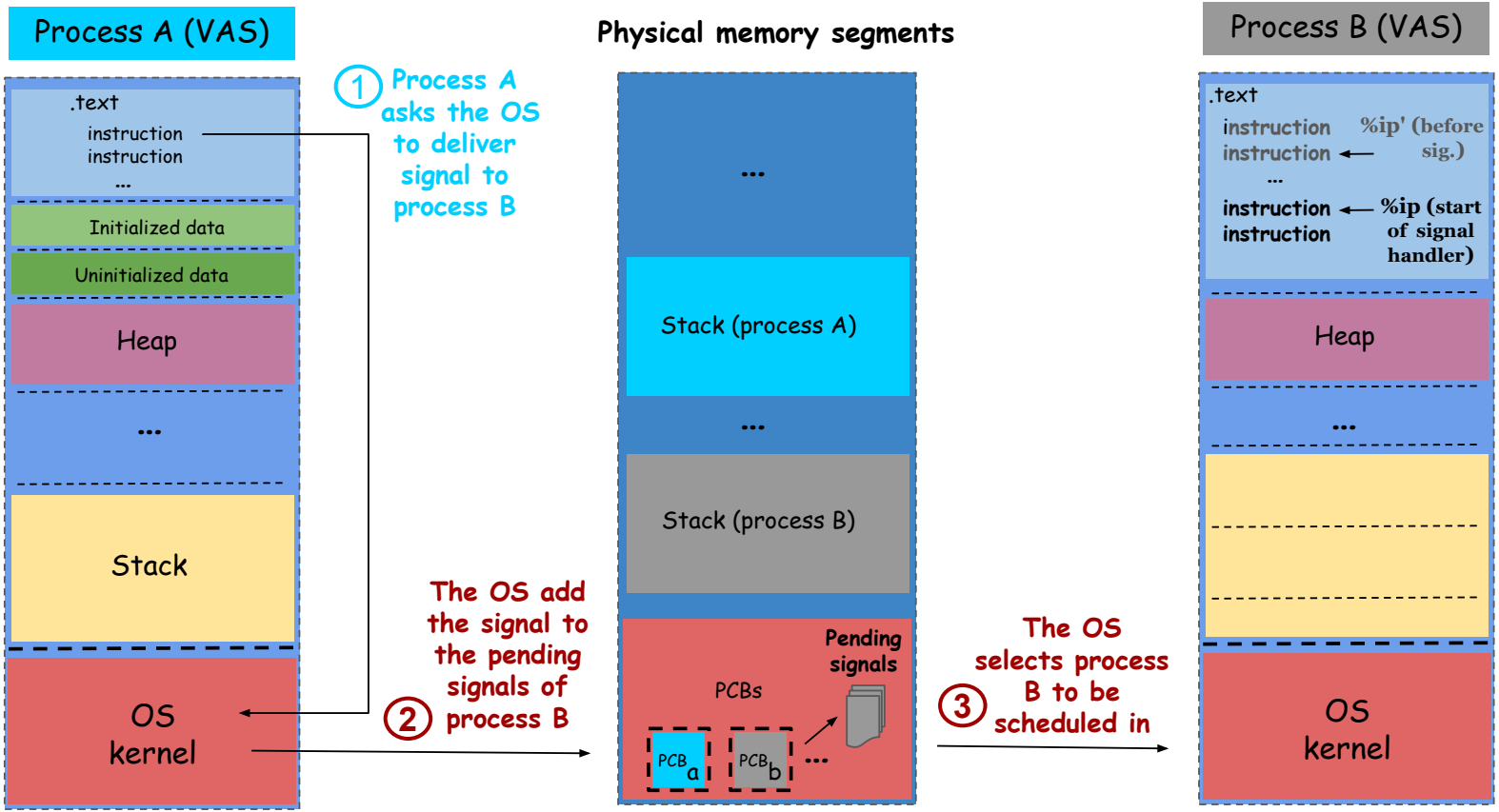
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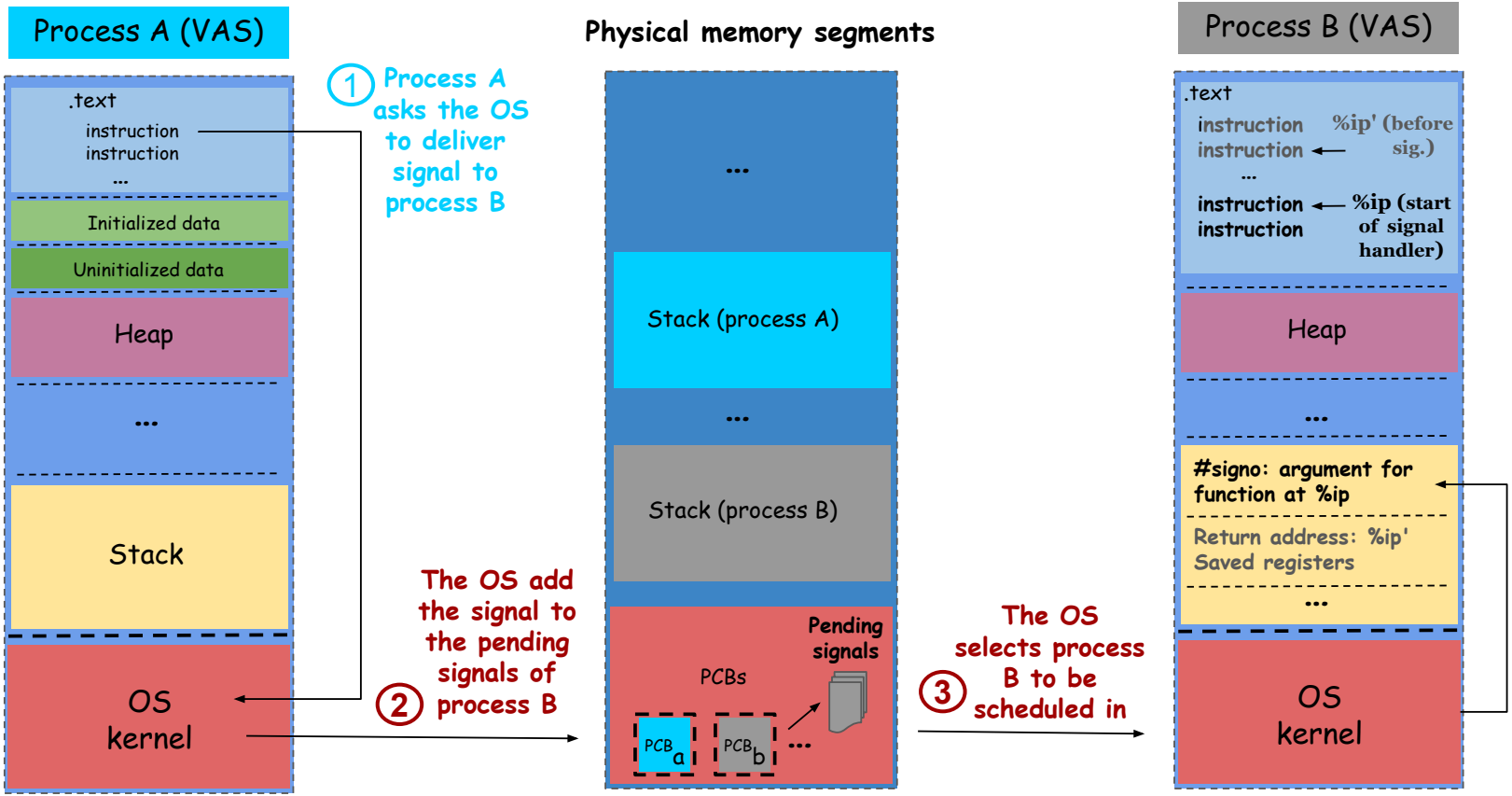
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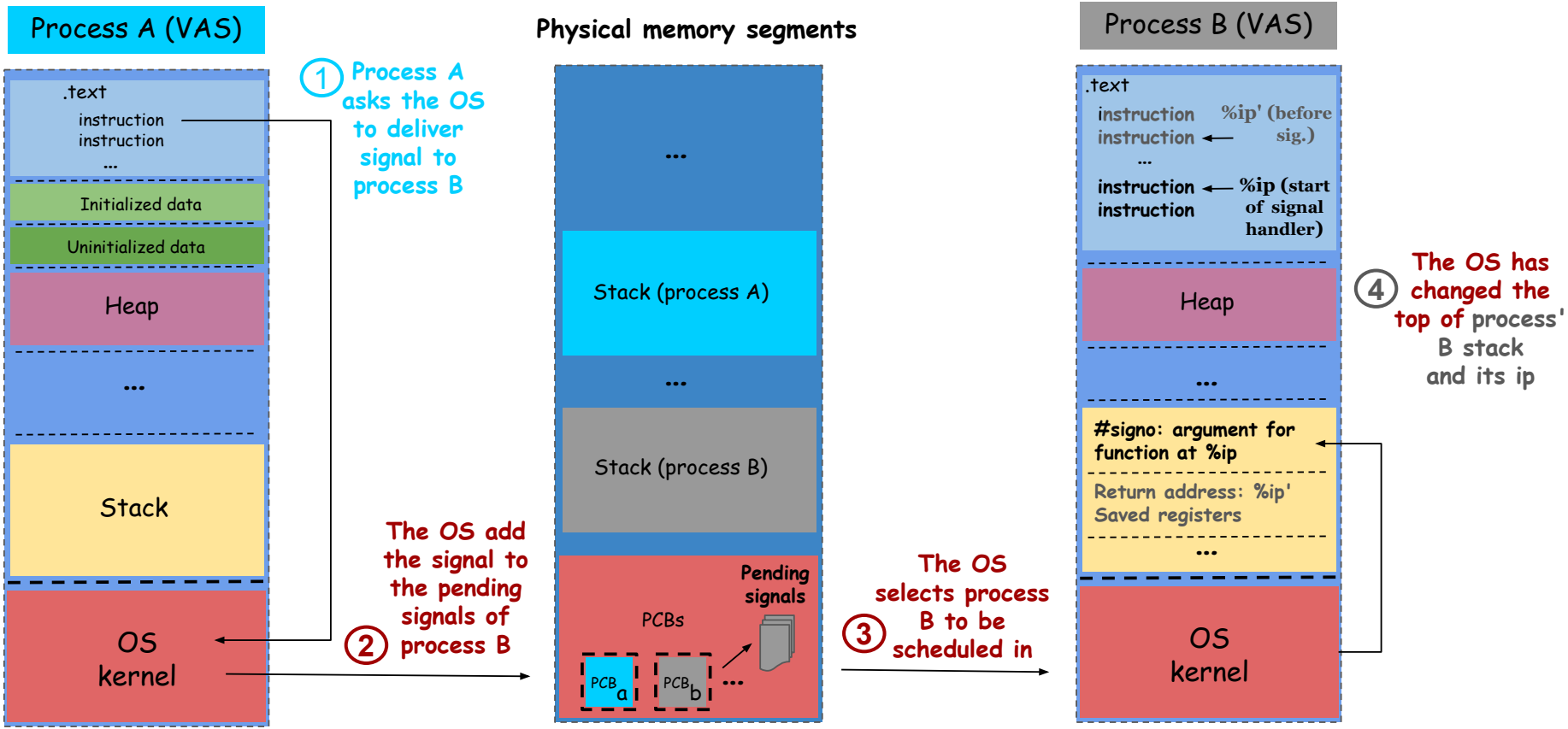
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> Sending a signal (Linux)

→ kill()
→ prepare_kill_siginfo()
→ kill_something_info()
→ kill_proc_info()
→ kill_pid_info()
→ kill_pid_info_type()
→ group_send_sig_info()
→ do_send_sig_info()
→ send_signal_locked()
→ __send_signal_locked()

> Handling a signal (Linux x86)

→ exit_to_user_mode_loop()
→ arch_do_signal_or_restart()
→ handle_signal()
→ setup_rt_frame()
→ x64_setup_rt_frame()

From an address translation error to a SIGSEGV

```
> do_translation_fault()
                |     do_page_fault()
                |       ...
                |       arm64_force_sig_fault(SIGSEGV, ...)
0.500 us        |         ...
                |         force_sig_fault()
                |           force_sig_info_to_task()
                |             send_signal_locked()
                |               __send_signal_locked()
0.666 us        |                 prepare_signal();
                |                   ...
                |                 complete_signal()
                |                   signal_wake_up()
                |                     signal_wake_up_state()
0.250 us        |                       wake_up_state()
                |                     try_to_wake_up_state
                |                       ...
0.333 us        |                     kick_process()
1.875 us        |                       ...
```

```c
int main(void) {
  char *p = 0x123;
  *p = 0;
}
```

This is only a small subset of all things the OS does when your program causes a SIGSEGV

 # How to enable kernel tracing

```
$ cd /sys/kernel/debug/tracing
$ echo function_graph > current_tracer
$ echo 114194 > set_ftrace_pid
$ echo 1 > tracing_on
$ cat trace > /tmp/kernel_trace.log
$ echo 0 > tracing_on
```

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- A SIGPIPE will be delivered to a process trying to write on a pipe whose read end is closed

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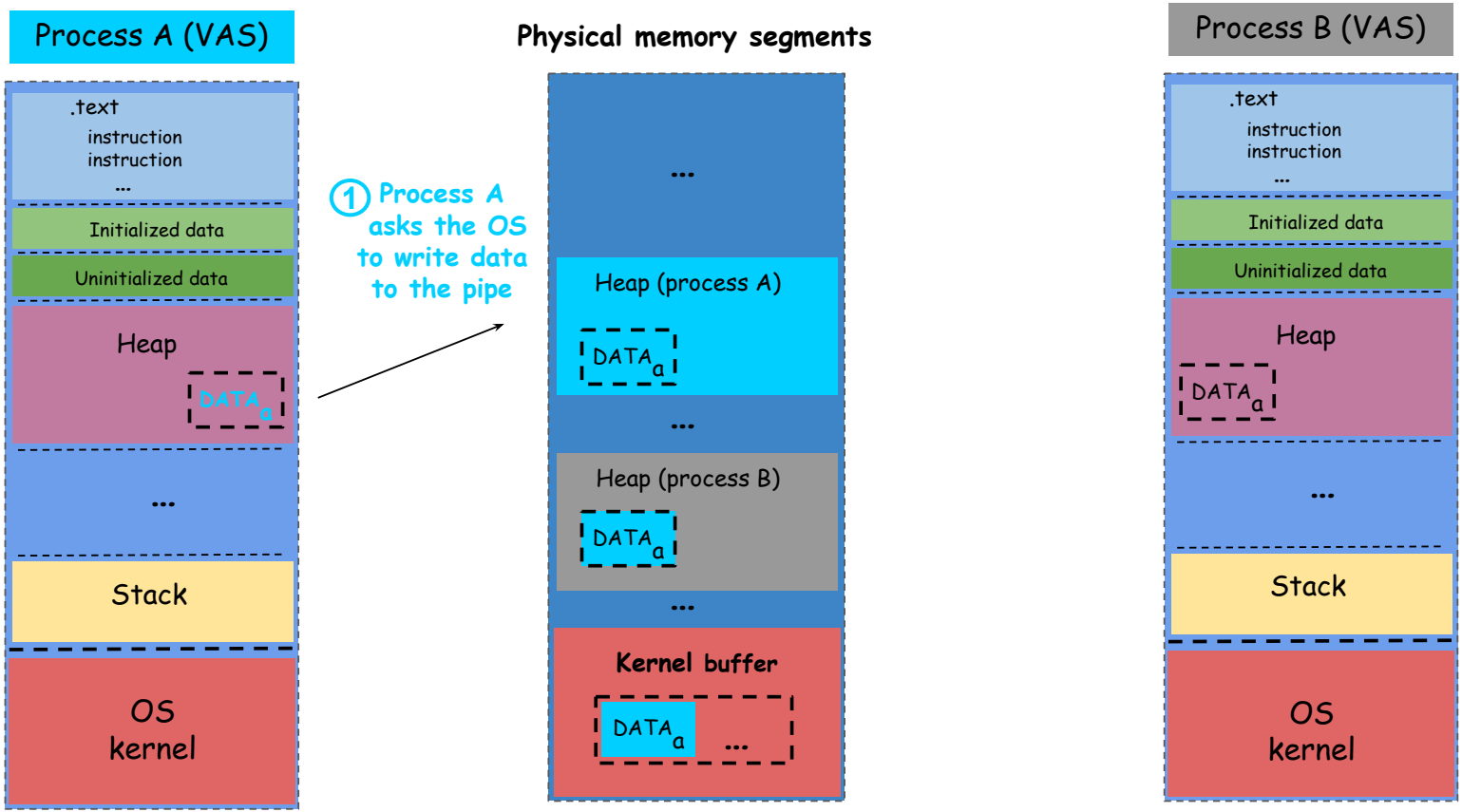
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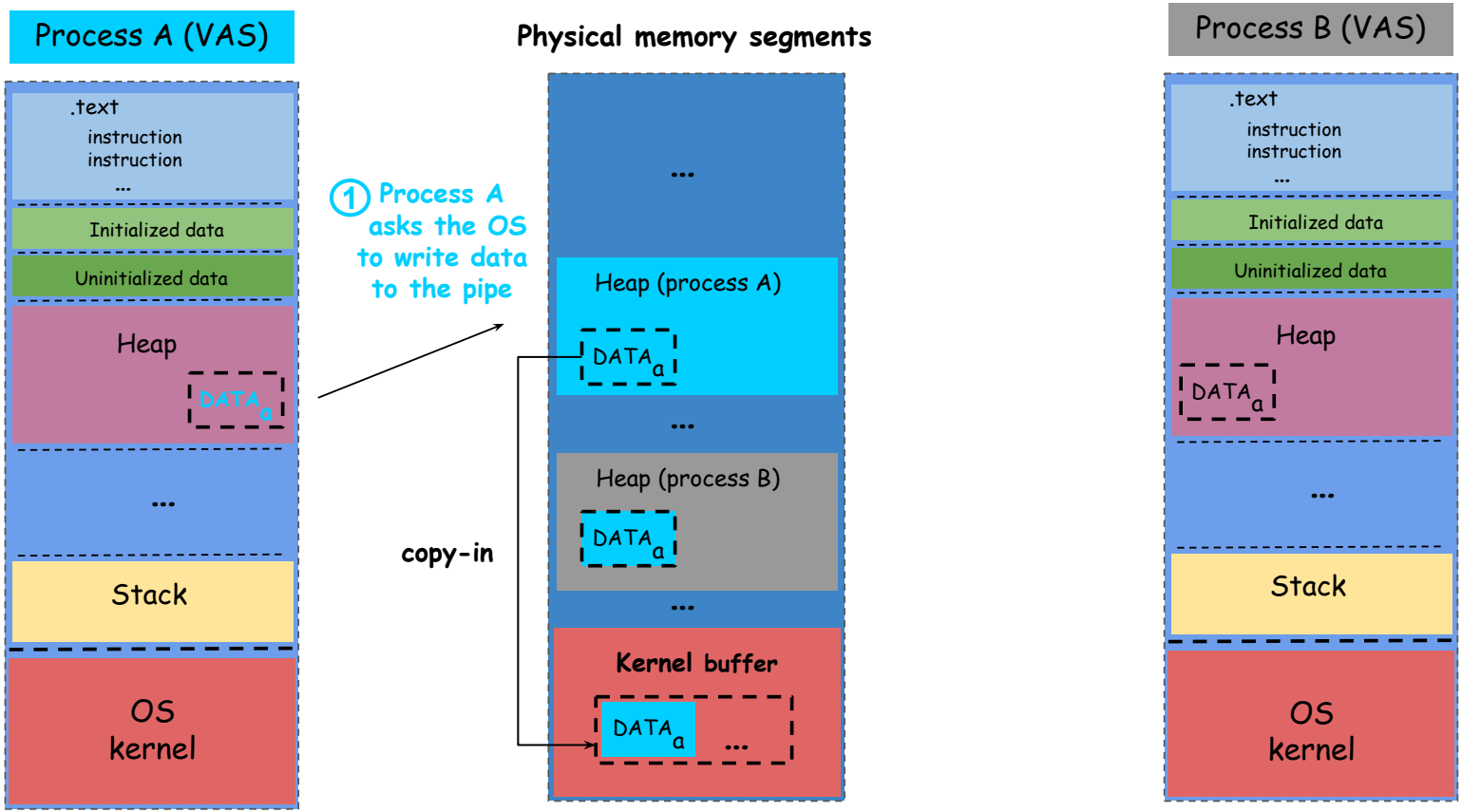
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- Bidirectional channels? See int socket(int domain, int type, int protocol)
- System-wide visible pipes? See int mkfifo(char *pathname, mode_t mode)

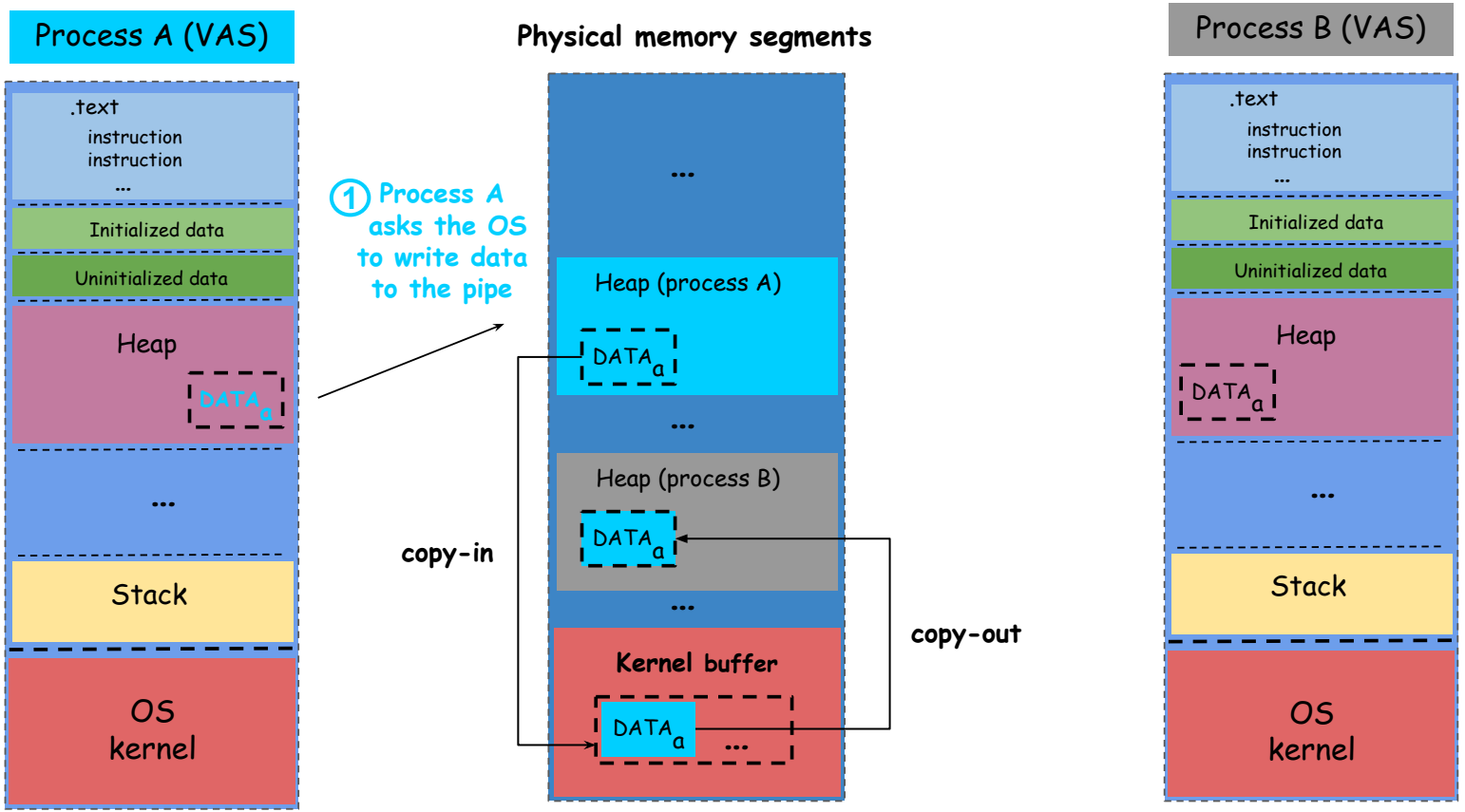
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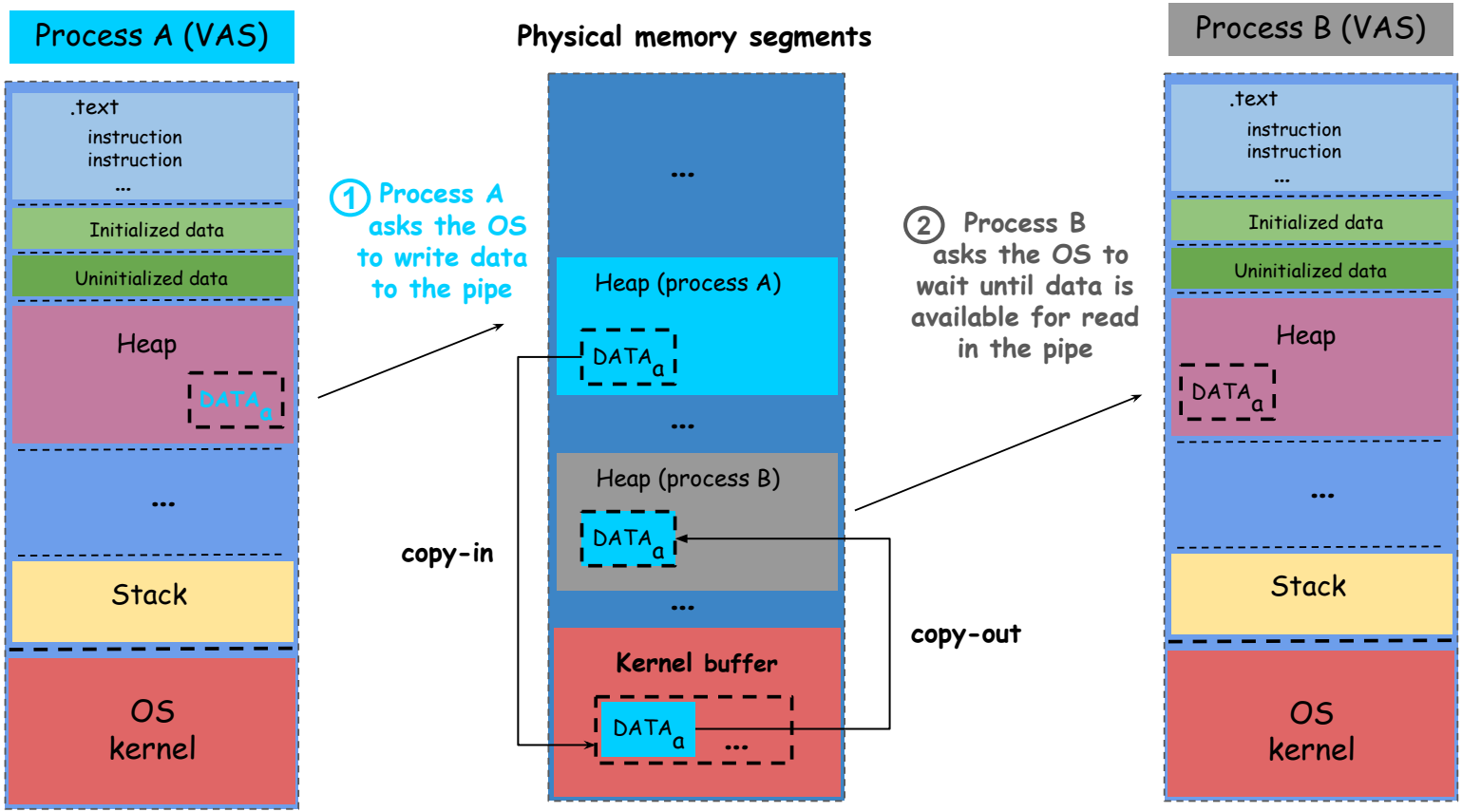
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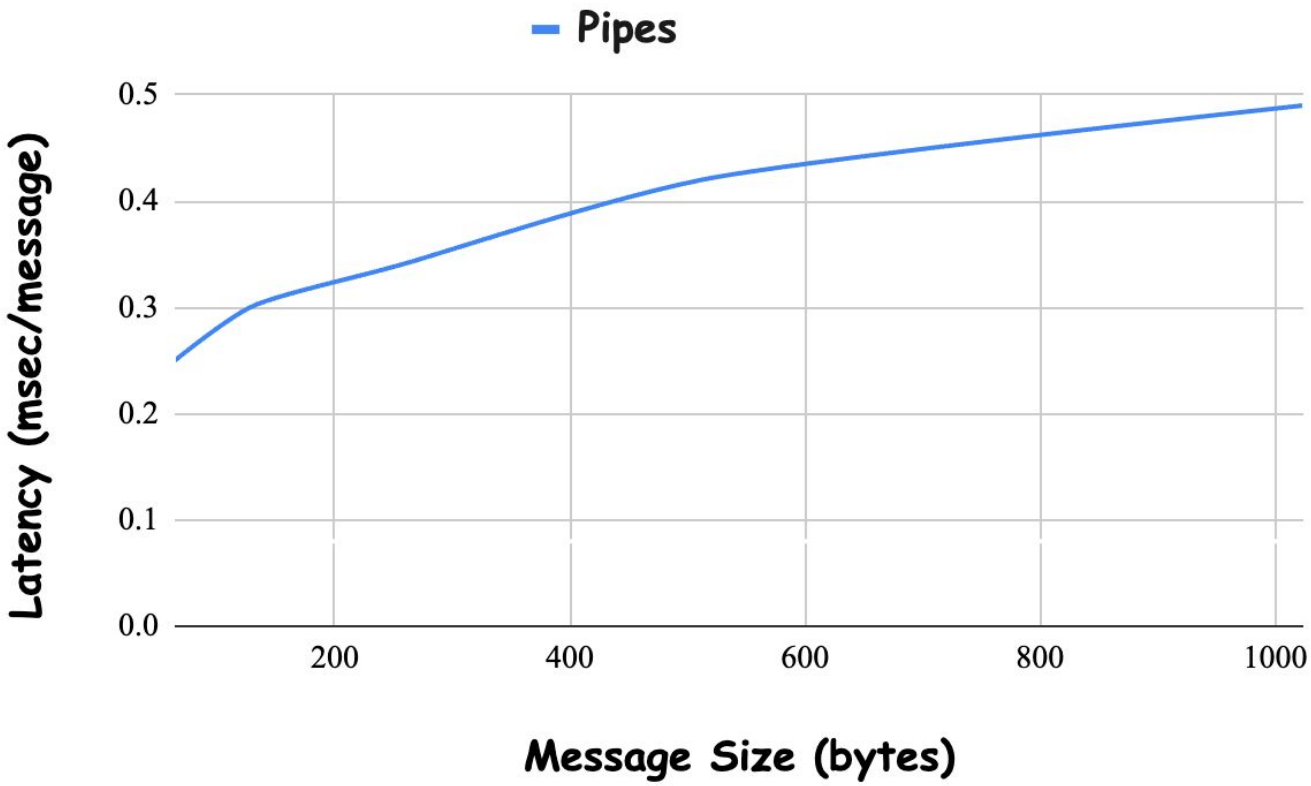
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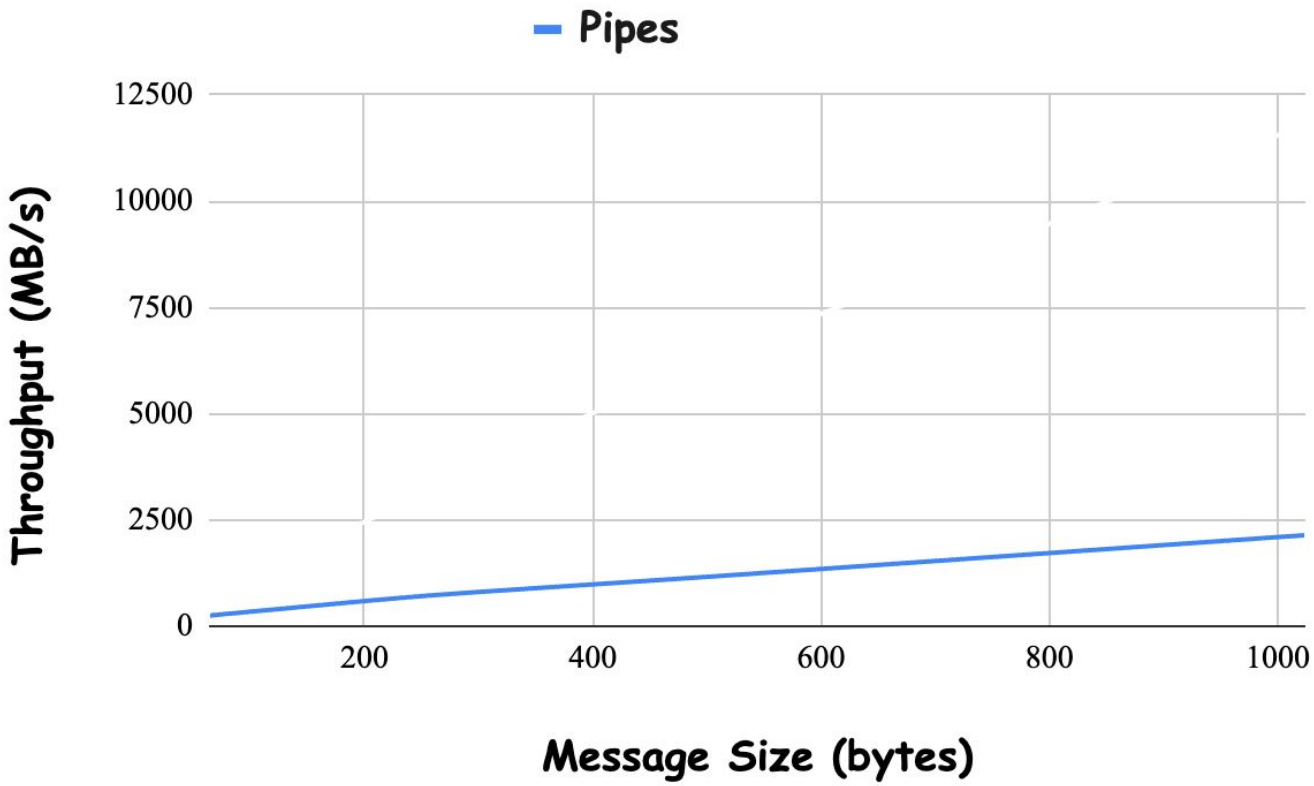
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  - Creates a shared memory (shm) segment of "size", associated with "key"
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- int shmat(int **shmid**, const void *shmaddr, ...)
  - Attaches the shm segment identified by shmid to the VAS of the calling process
  - If shmaddr is NULL, the OS chooses an unused virt. address to attach the segment

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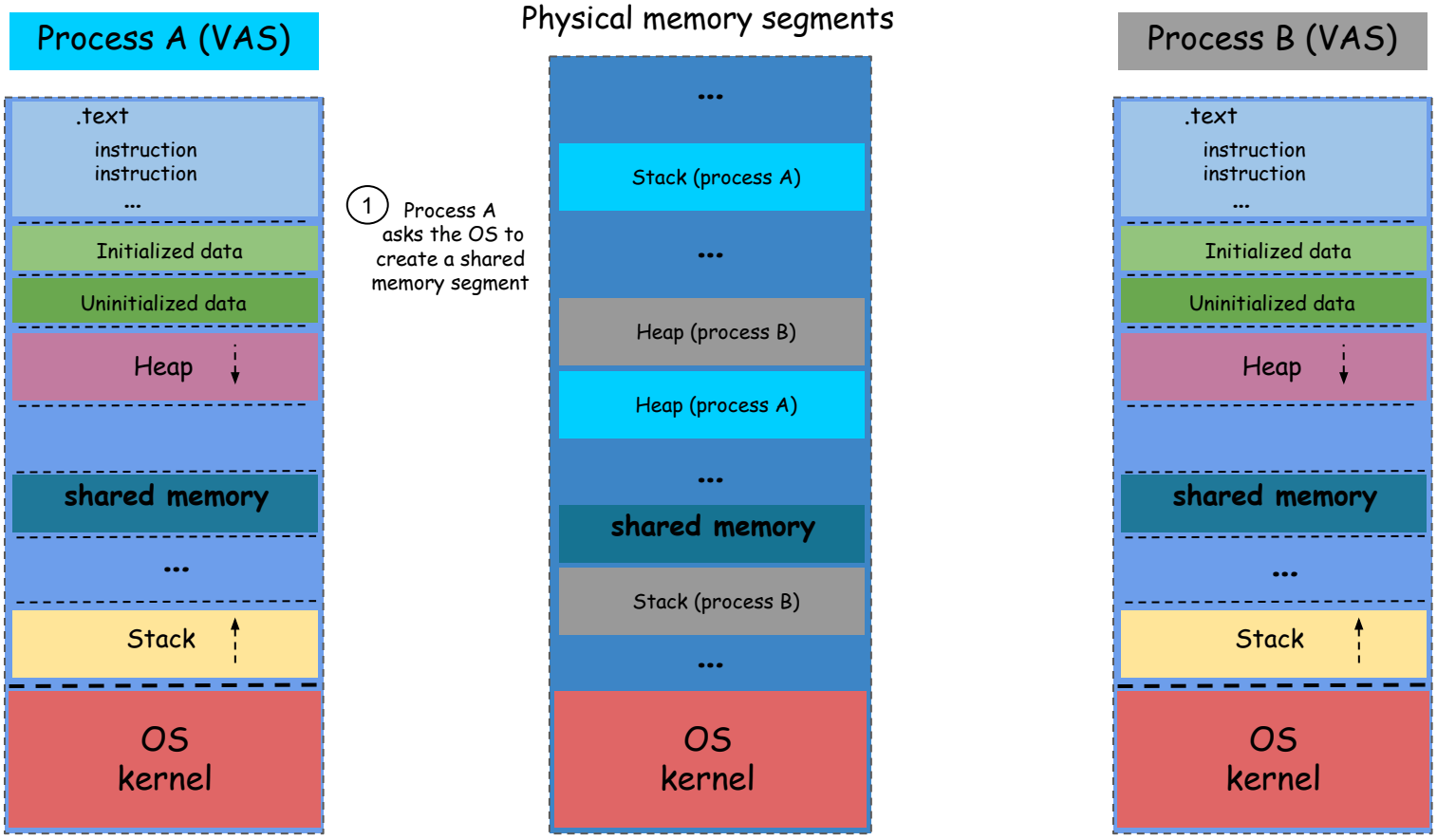
- Little responsibility ⇒ Wait for a message to be delivered
- **Slow**: Two copies (in/out) are required on every message exchanged

› How can processes avoid this overhead? **Ask the kernel to point directly to a memory region that is shared among processes (shared memory)**

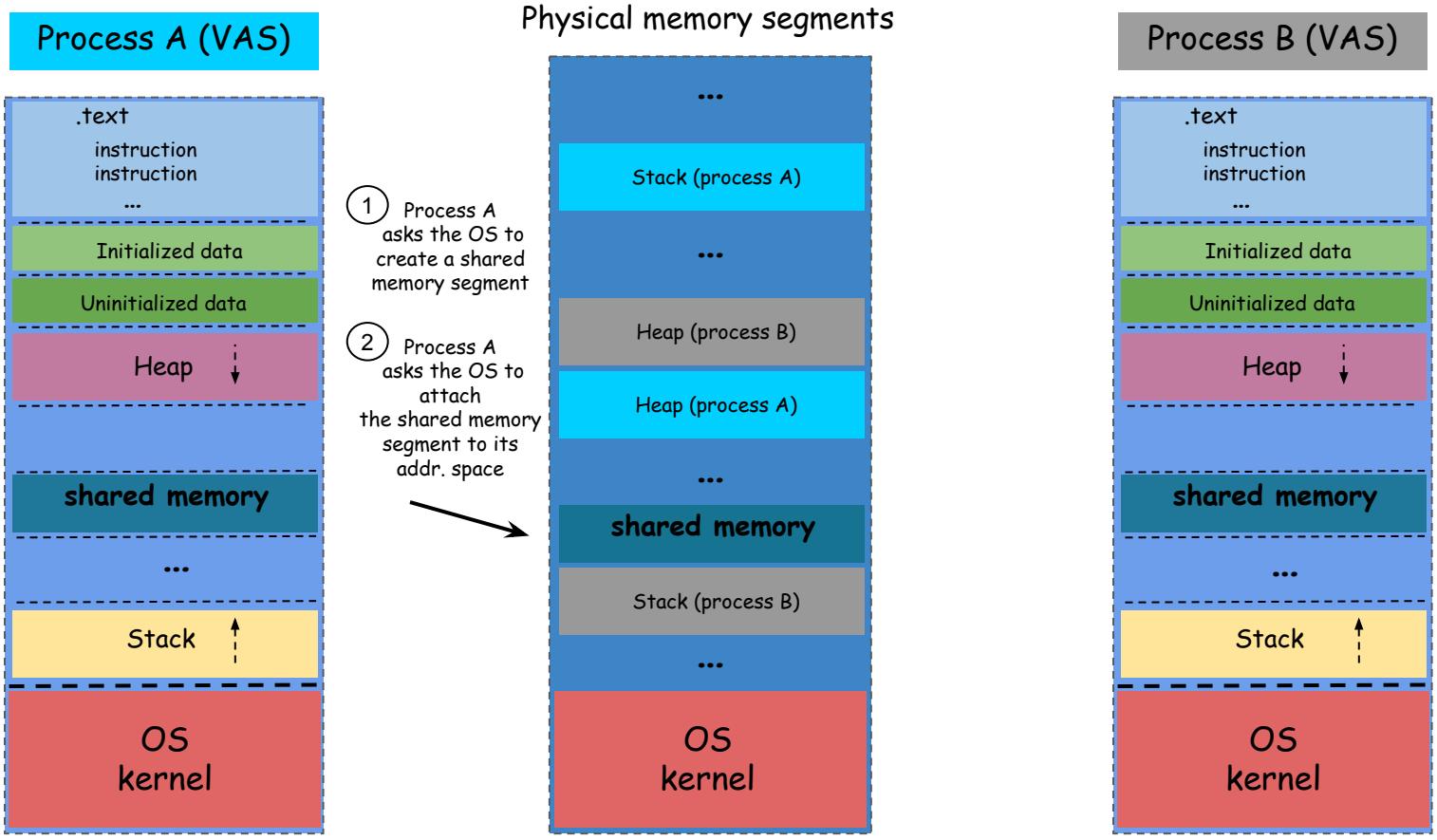
› Zero unnecessary copies

- New powers ⇒ New responsibilities
- Synchronization ⇒ More on this drama later

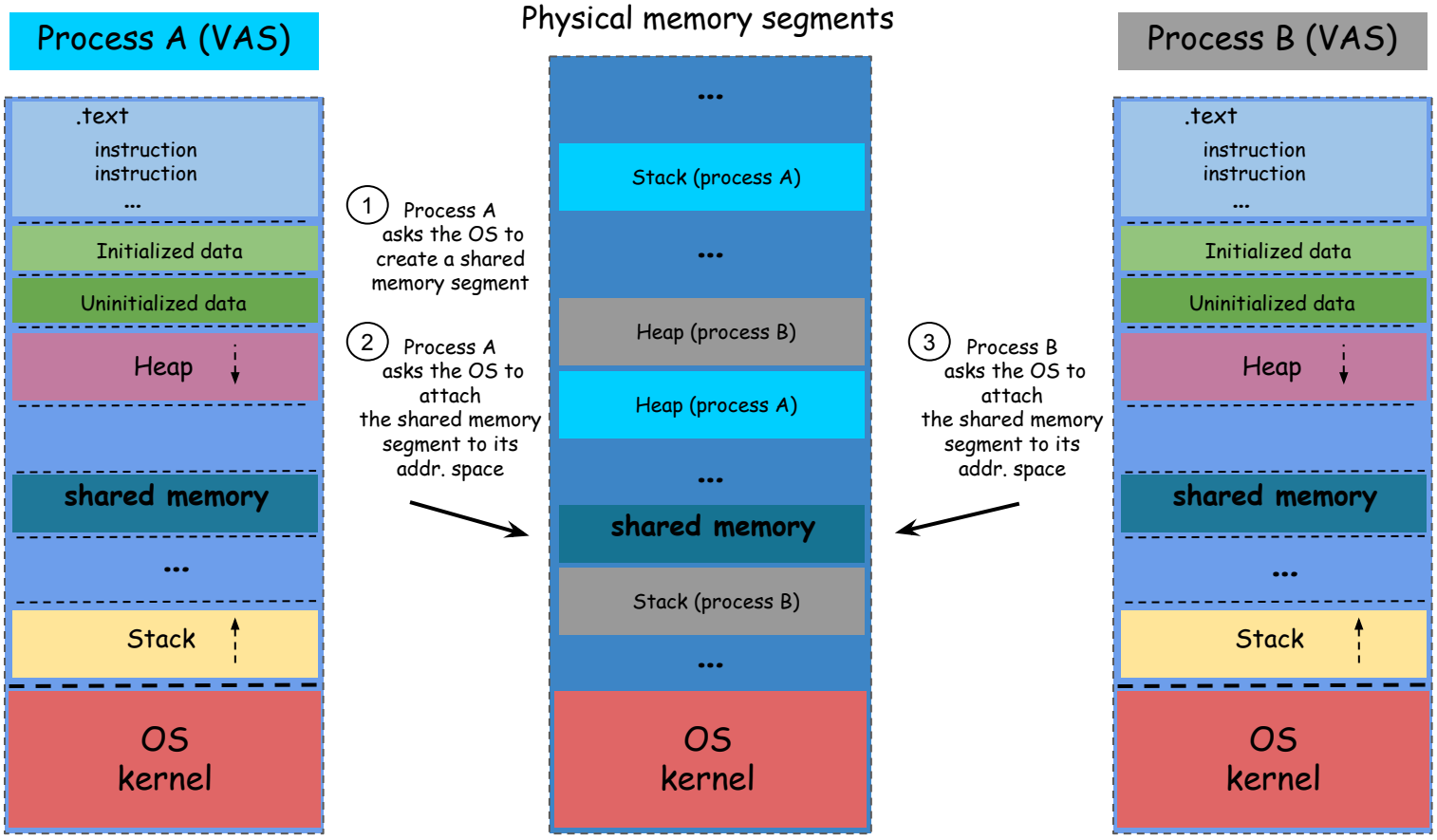
Synchronous IPC: Shared memory



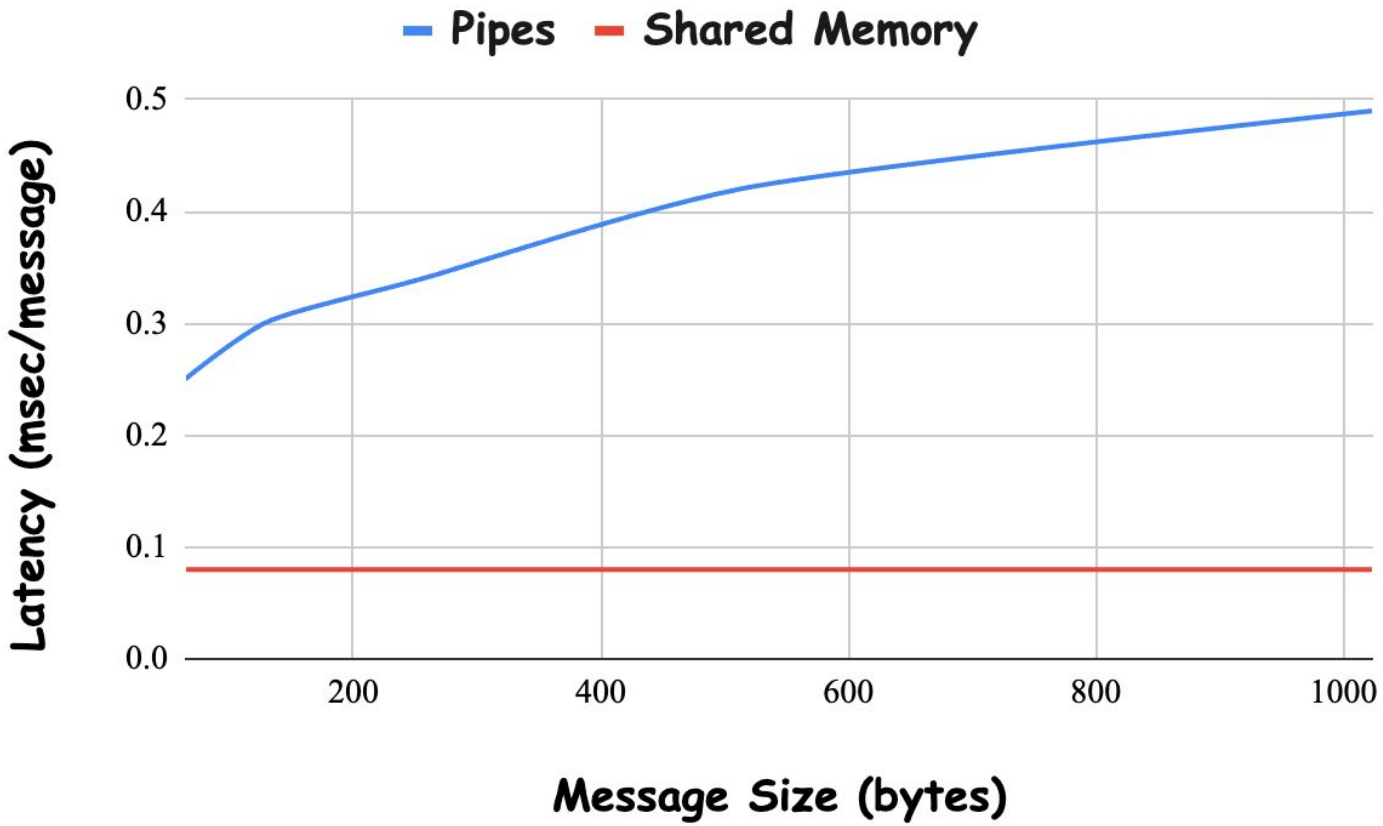
Synchronous IPC: Shared memory



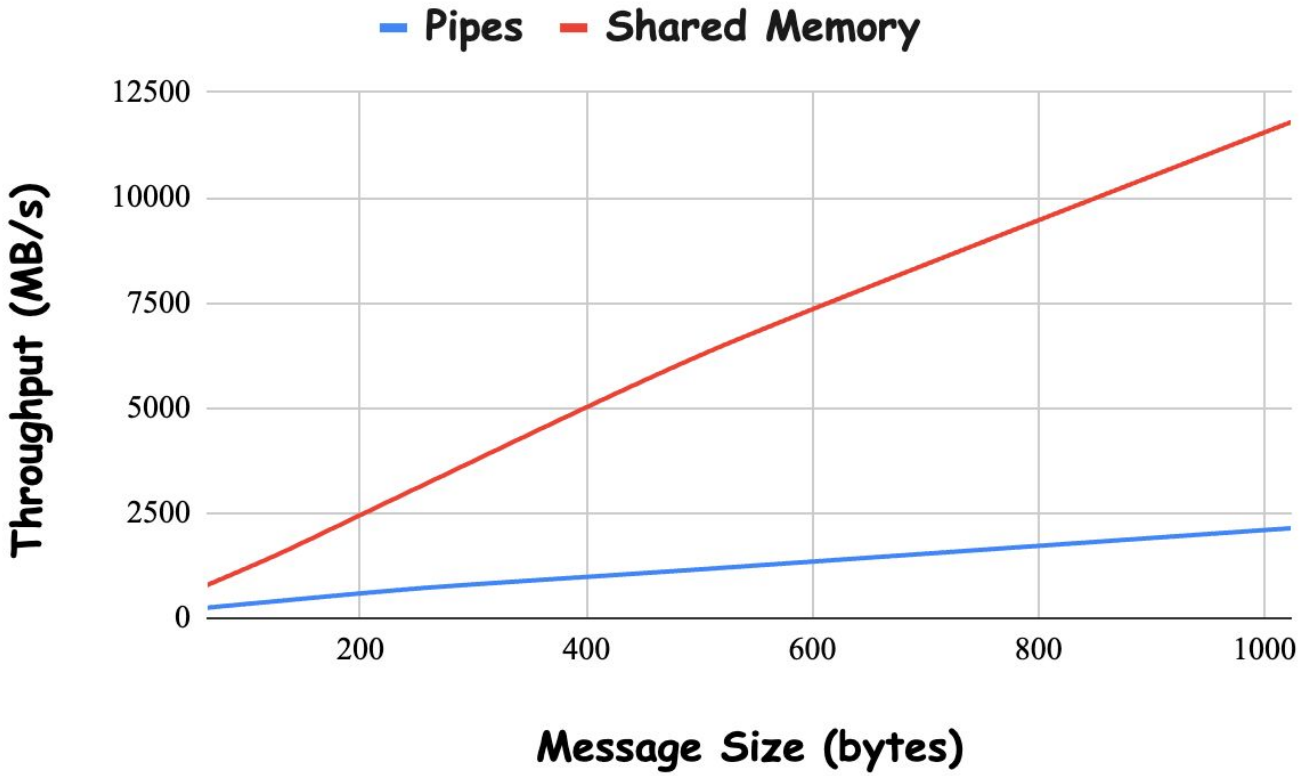
Synchronous IPC: Shared memory



Synchronous IPC: Shared memory vs Pipes



Synchronous IPC: Shared memory vs Pipes




Th-Th-Th-That's All Folks