Operating Systems and Concurrency

Introduction 3

COMP2007

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Recap

Last Lecture

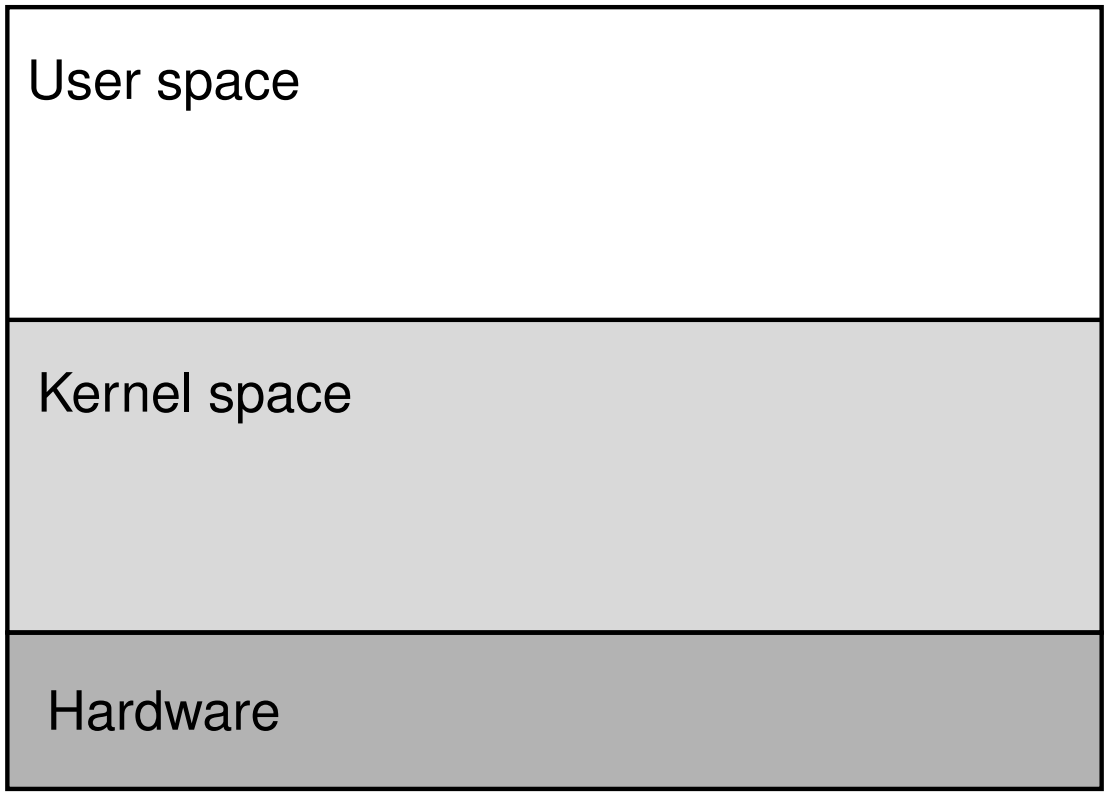
1. Operating system **kernel** design closely linked to hardware capabilities
2. **Registers** provide data consumed by the CPU
3. The **MMU** translates **logical** to **physical addresses** abstracting the details of the memory hardware

Goals for Today

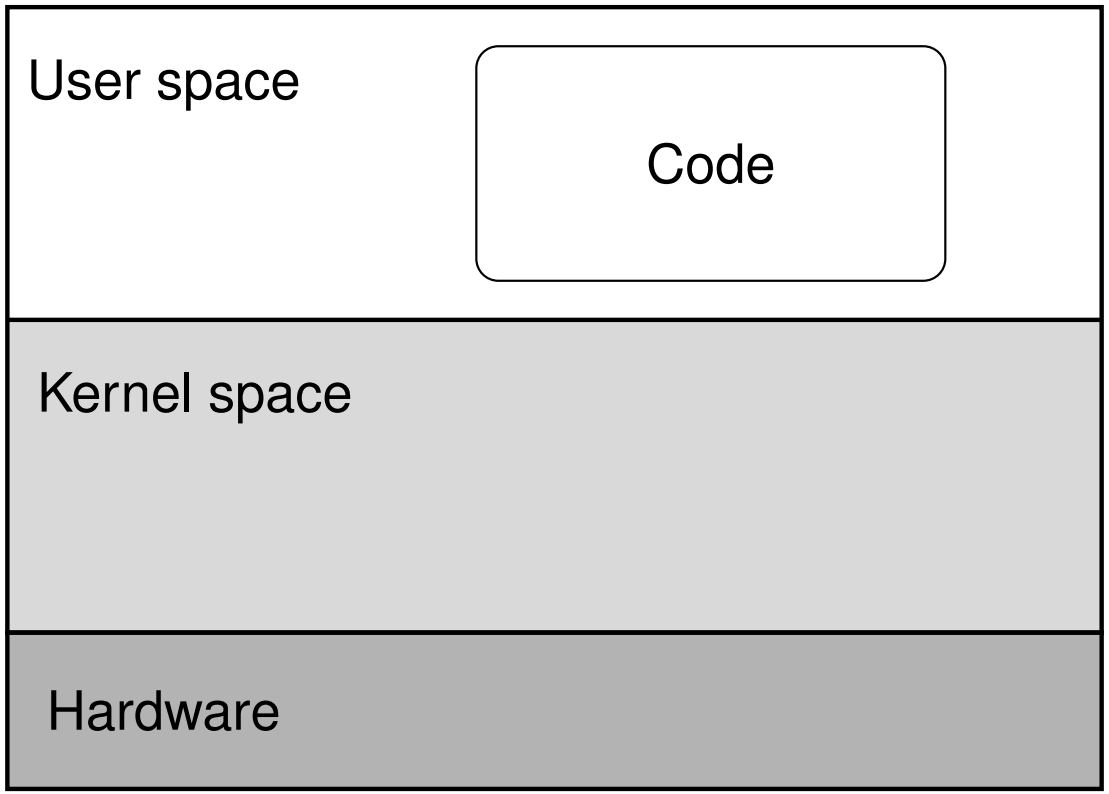
Overview

- **Kernel and user space**
- **Interrupts**
- **System calls**
- **The C programming language** - an operating systems perspective.

Kernel and user space



Kernel and user space



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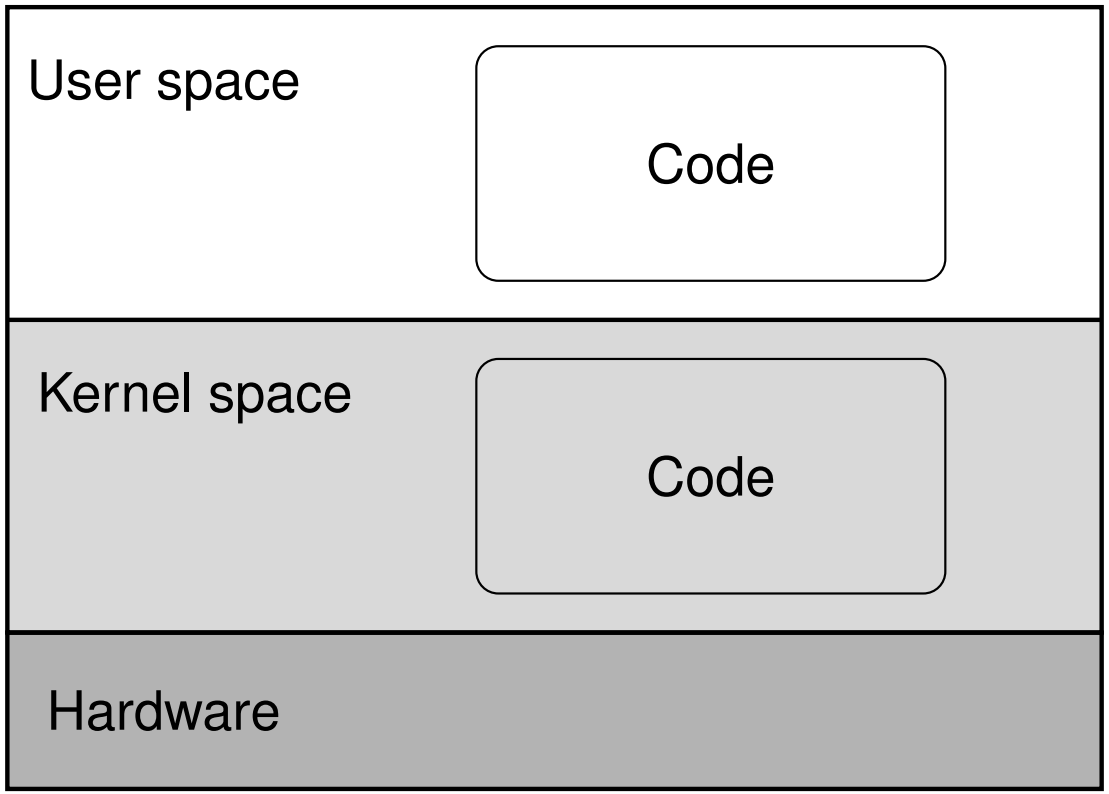

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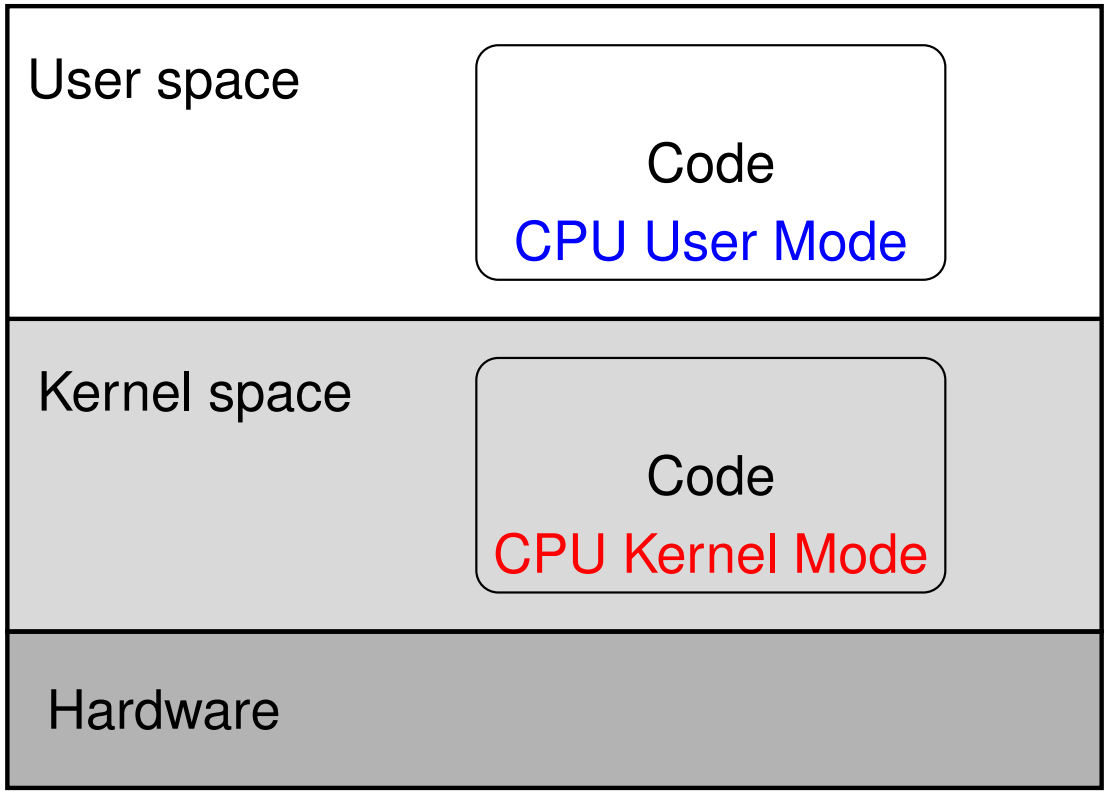

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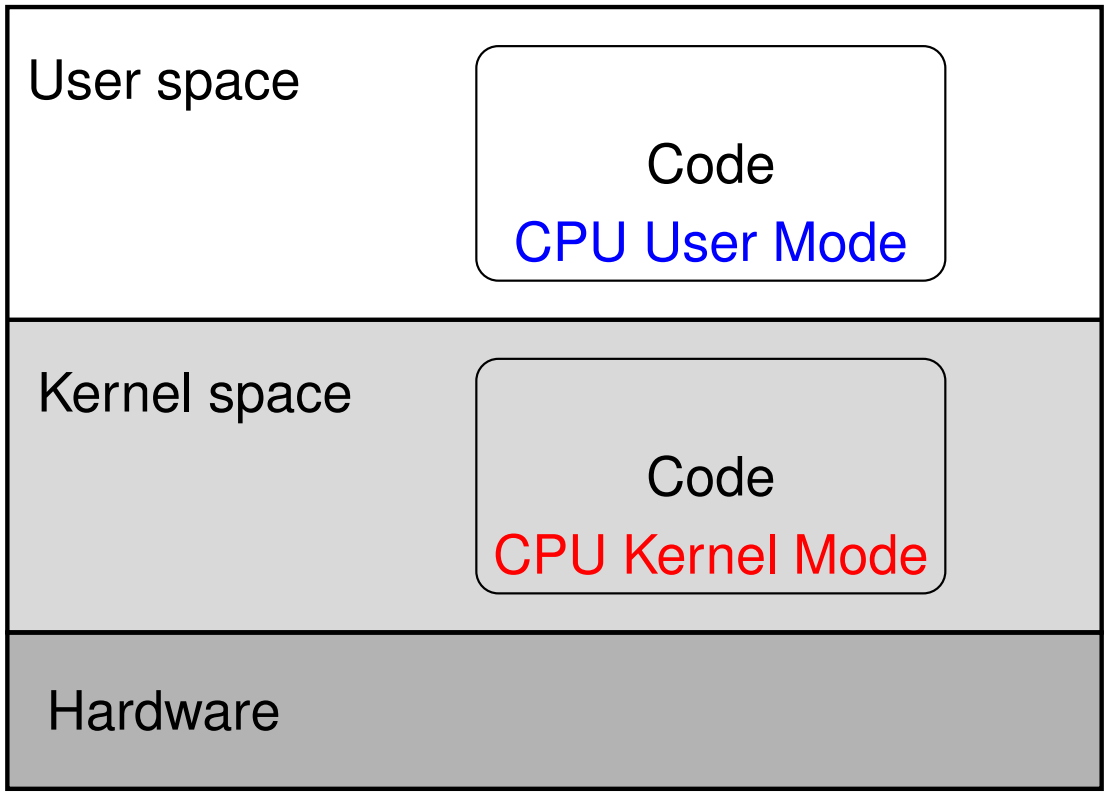

Terminology

The code running in kernel mode is often referred to as the **kernel**. Although this is the core of an operating system, typically they will also have user processes for user interfaces, scheduling daemons, ...

Interrupts

Entering the kernel to respond to events

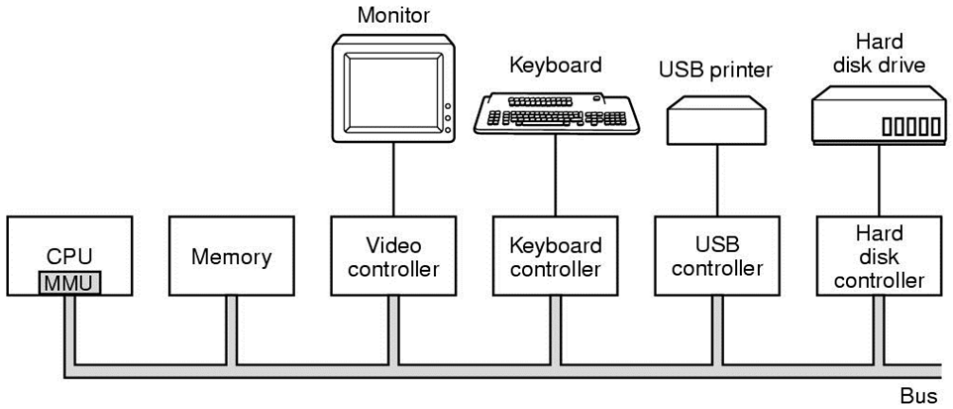

Figure: Simplified computer model (Tanenbaum, 2014)

The CPU cannot usefully live in isolation

Programs, and therefore the CPU, must be able to respond to various events.

For example:

- Connected hardware devices might need to communicate
- The passing of time
- Bad things happening - division by zero, hardware faults...

Interrupts

Entering the kernel to respond to events

Interrupts are the mechanism by which such events are handled.

- Abstractly, **an interrupt is a mechanism for changing the normal flow of execution**
- Can happen **asynchronously**, triggered by unpredictable factors external to the CPU, such as user input
  - Sometimes the term **interrupt** is reserved for this class
- Can also happen **synchronously**, triggered directly by the CPU executing an instruction
  - Sometime the term **exception** is used for this class

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3. The CPU records aspects of its current state, **switches to kernel mode**, and runs code in a **handler** to service the interrupt
4. Once completed, the CPU is returned to processing other tasks

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  - Ideally handling interrupts should not take long
  - Handlers may split work into a **top** component dealt with immediately, and a **bottom** component scheduled to be dealt with later

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- Interrupts may be interrupted by other interrupts - it must be possible to **nest** interrupt handlers

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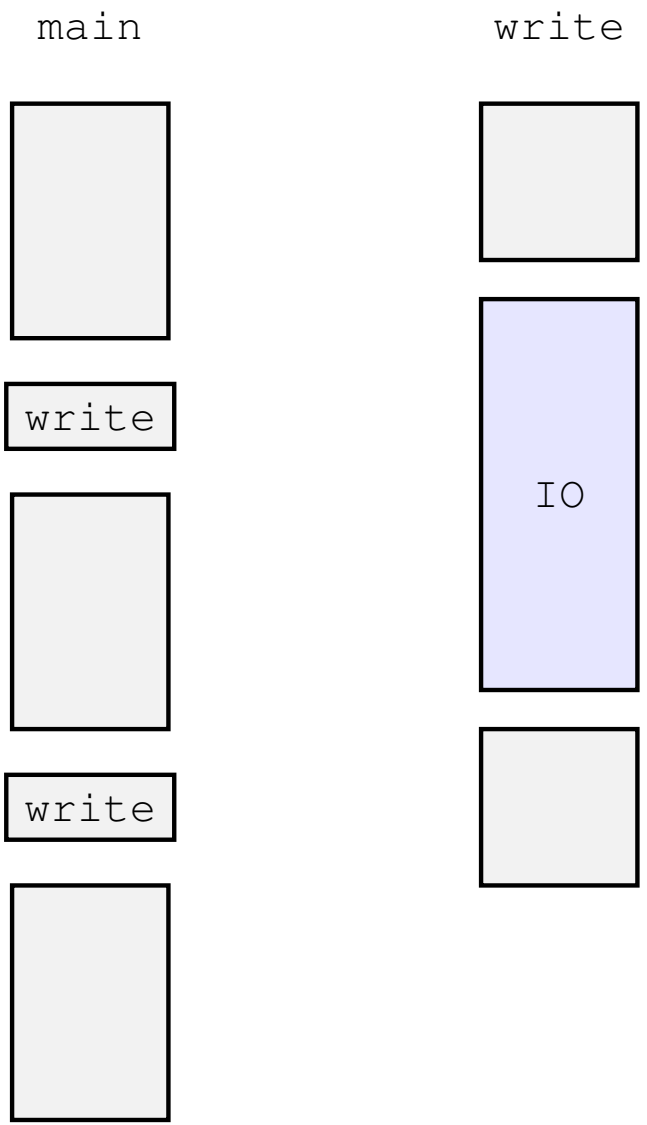
- Interrupts may be interrupted by other interrupts - it must be possible to **nest** interrupt handlers
- Sometimes critical code cannot be interrupted and they must be temporarily disabled

Interrupts

CPU utilisation

Blocking IO

Naive IO which wastes CPU cycles waiting for slow devices to respond.



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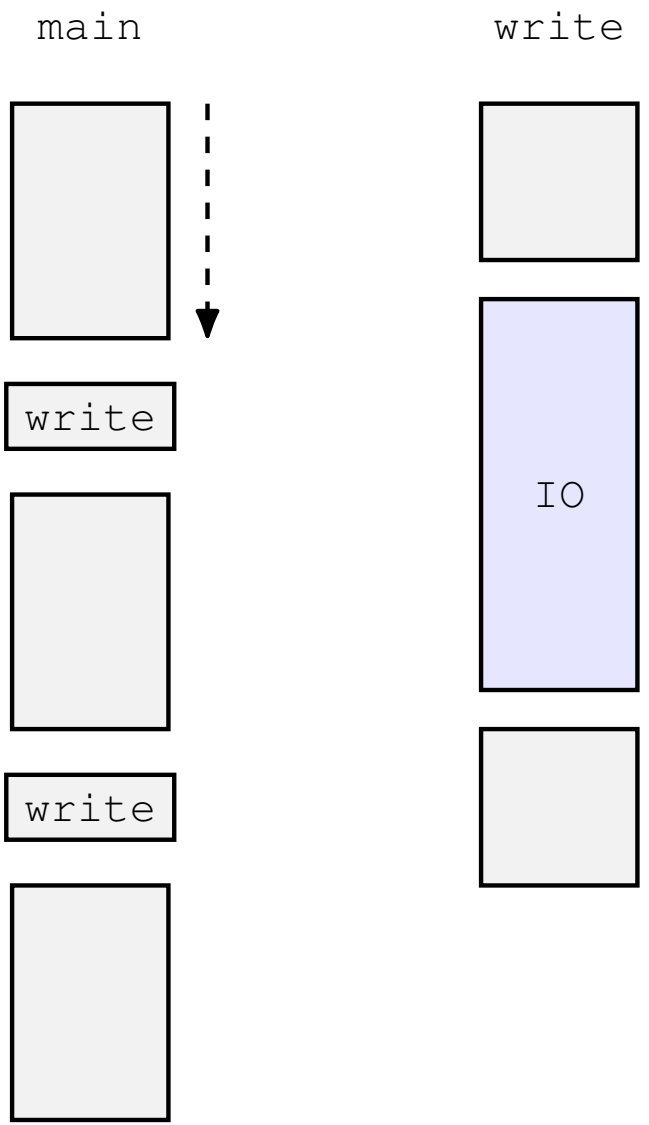

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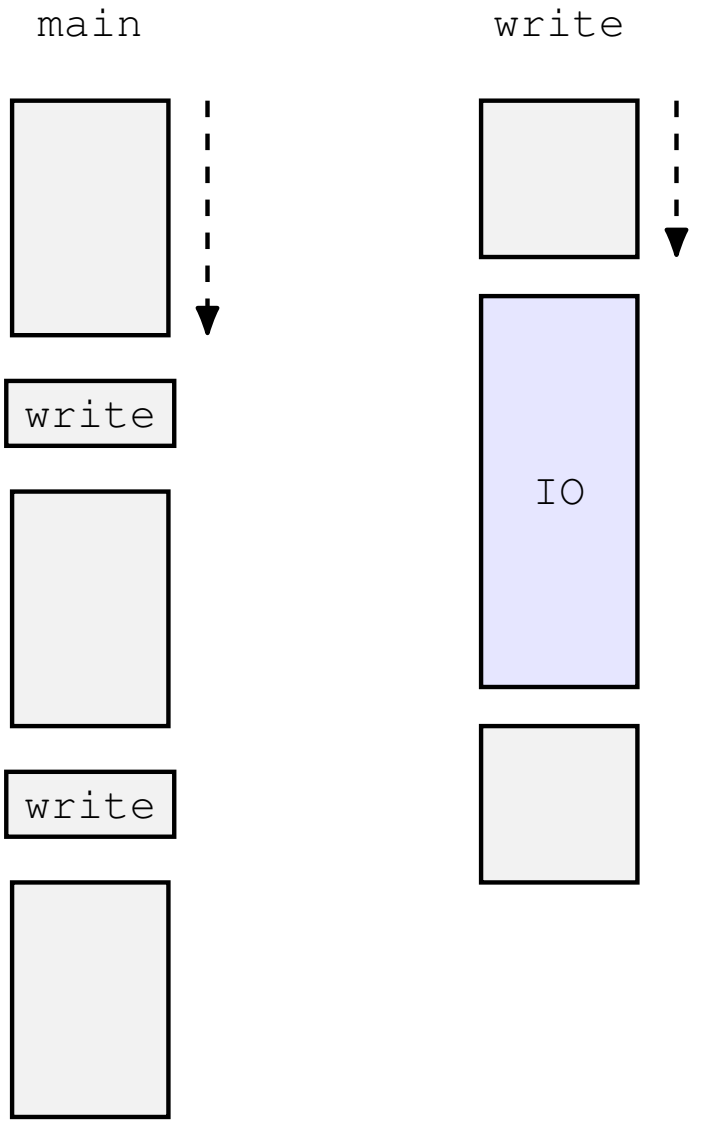

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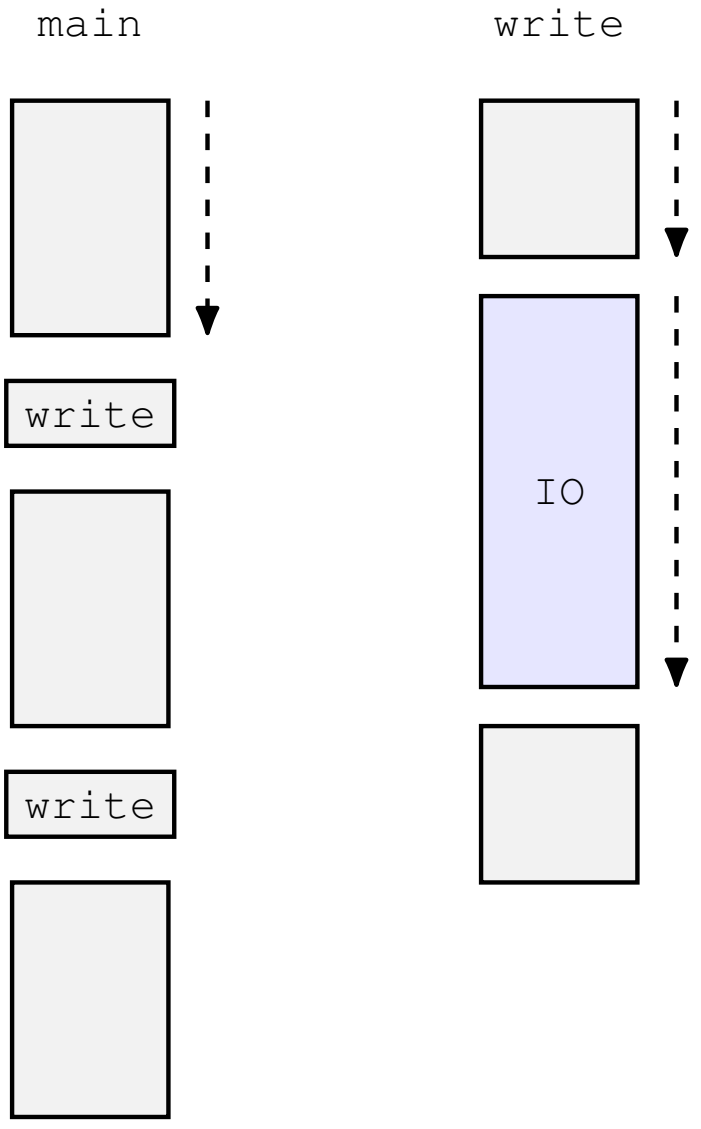

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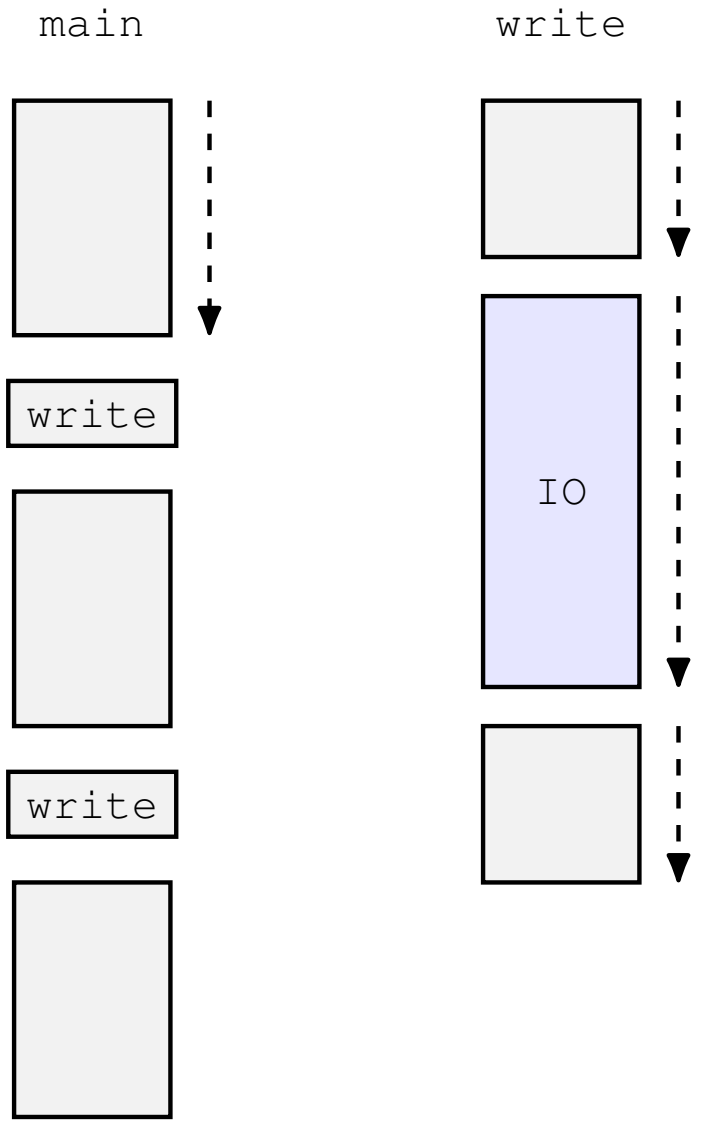

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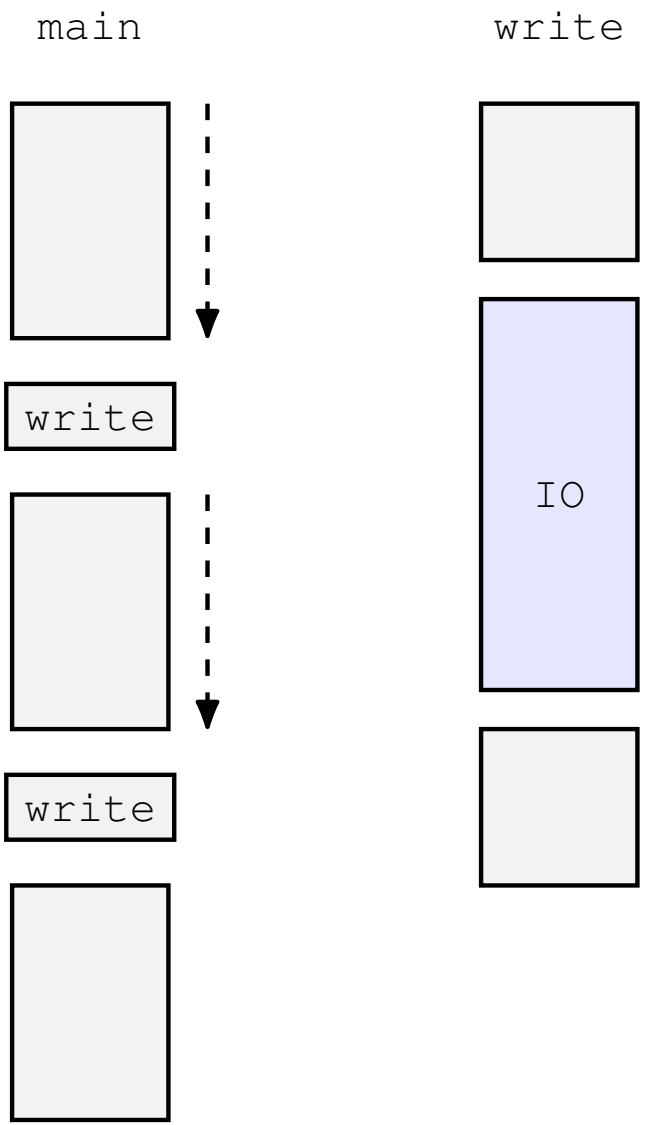

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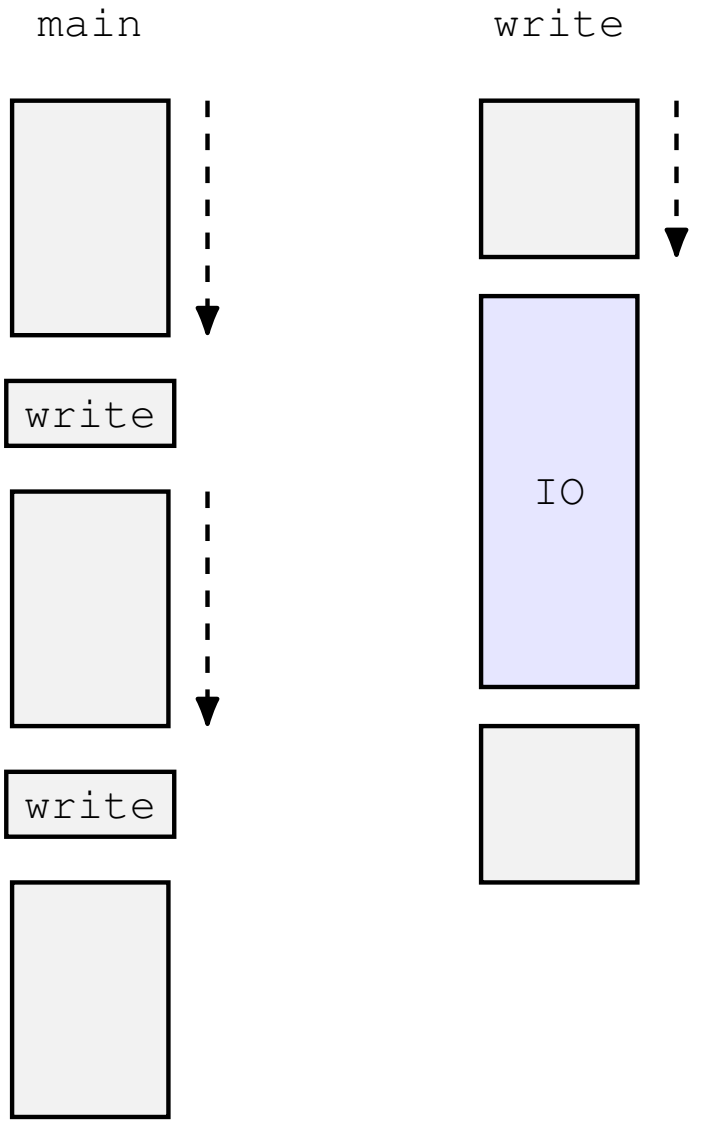

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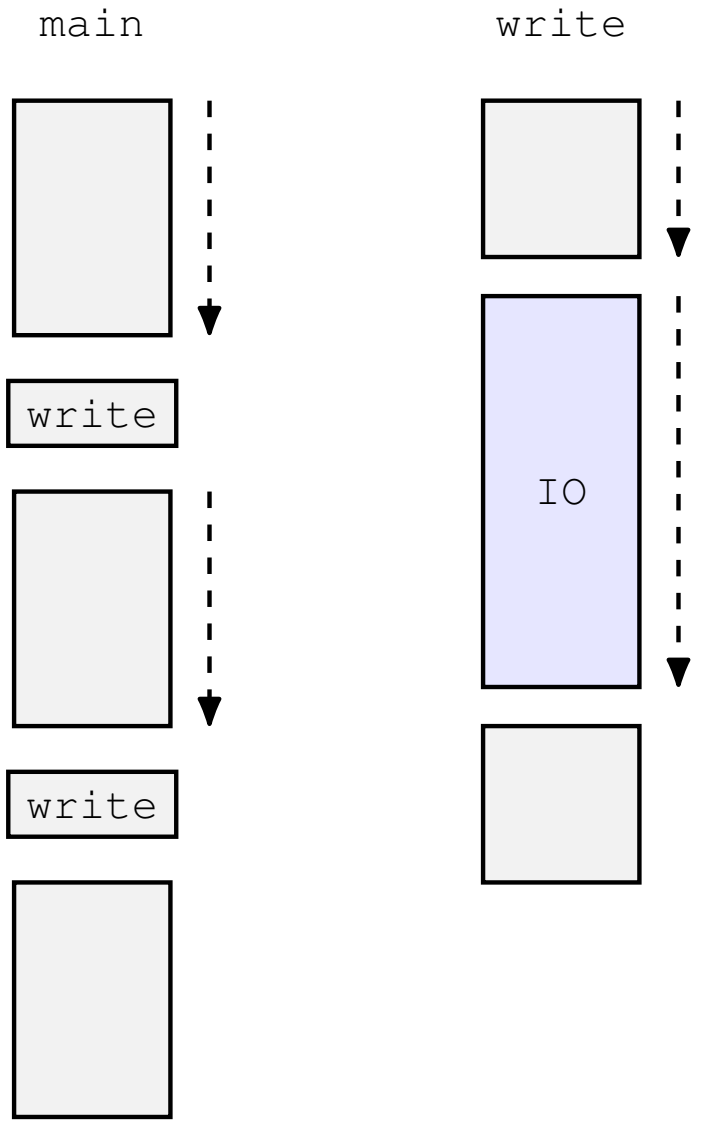

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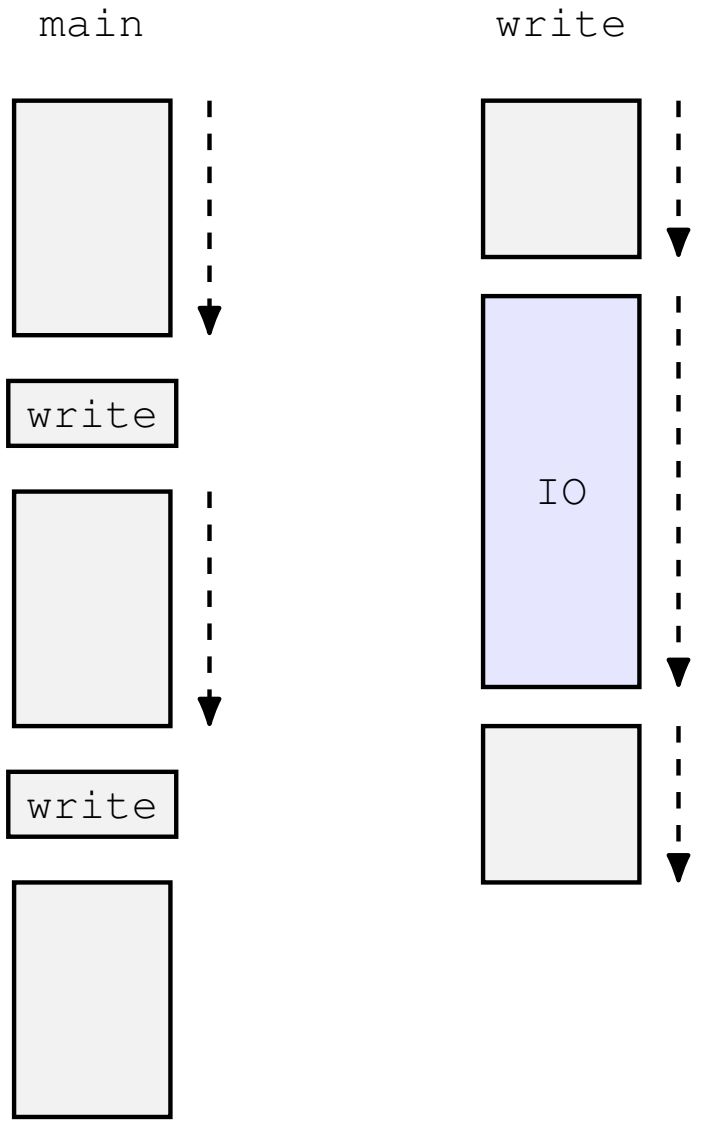

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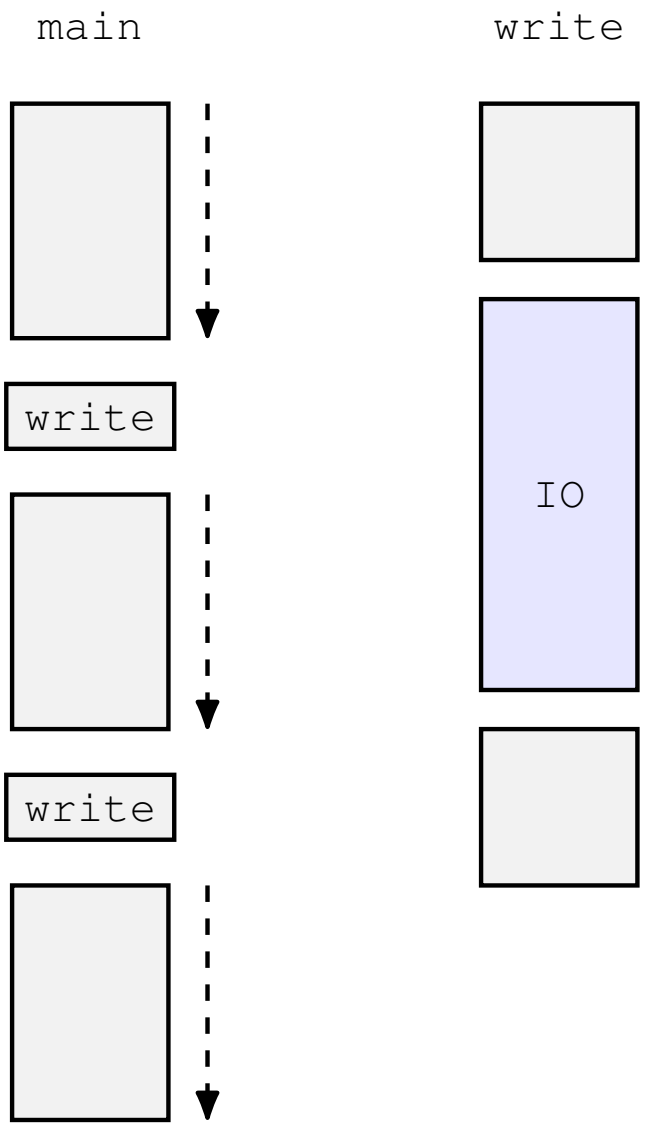

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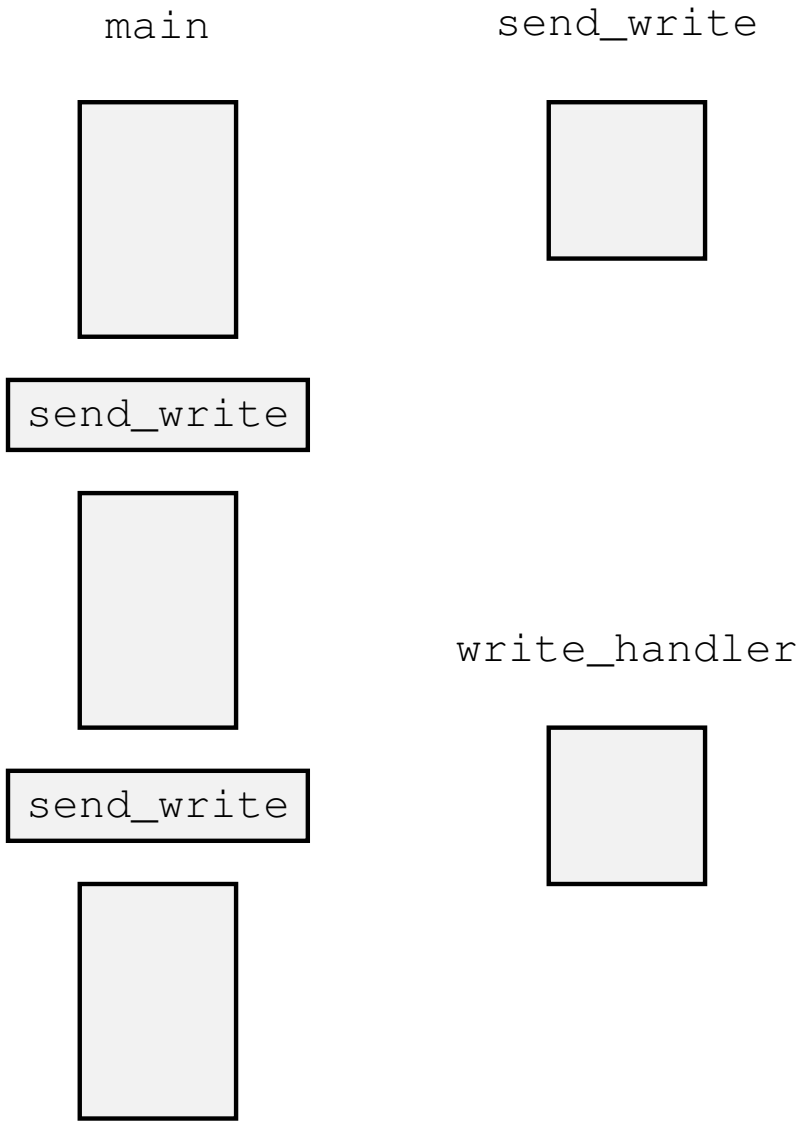

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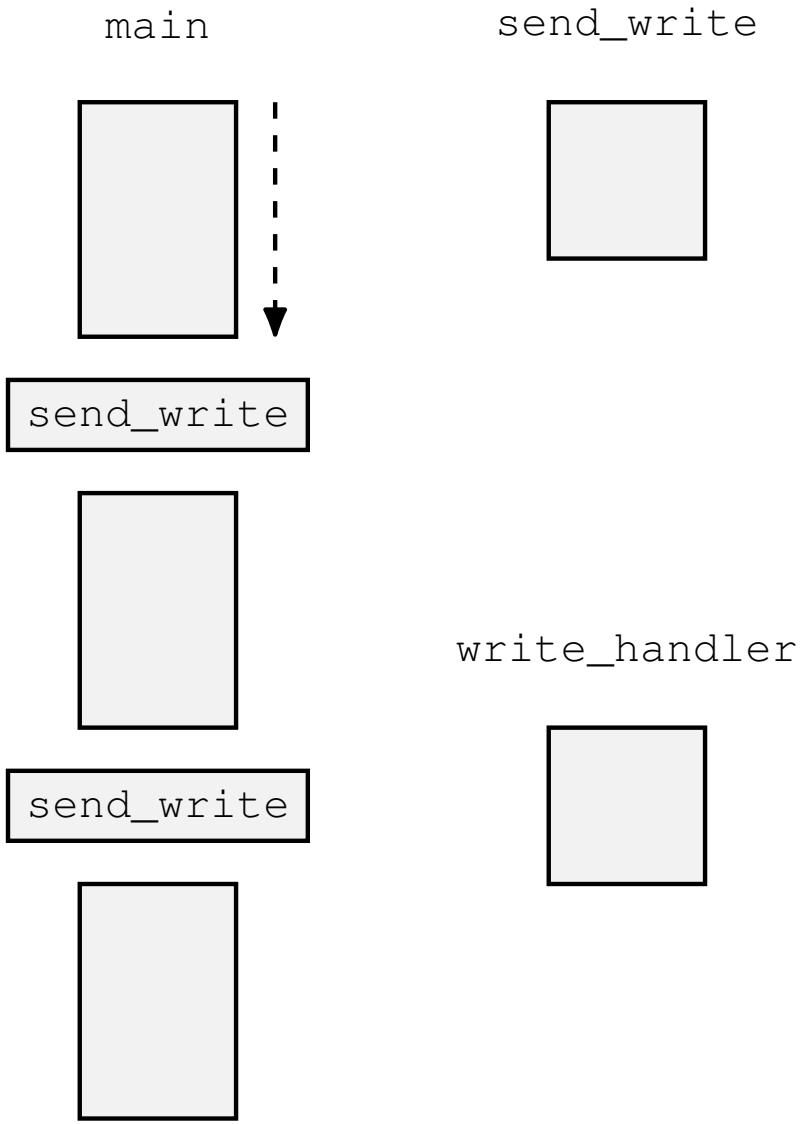

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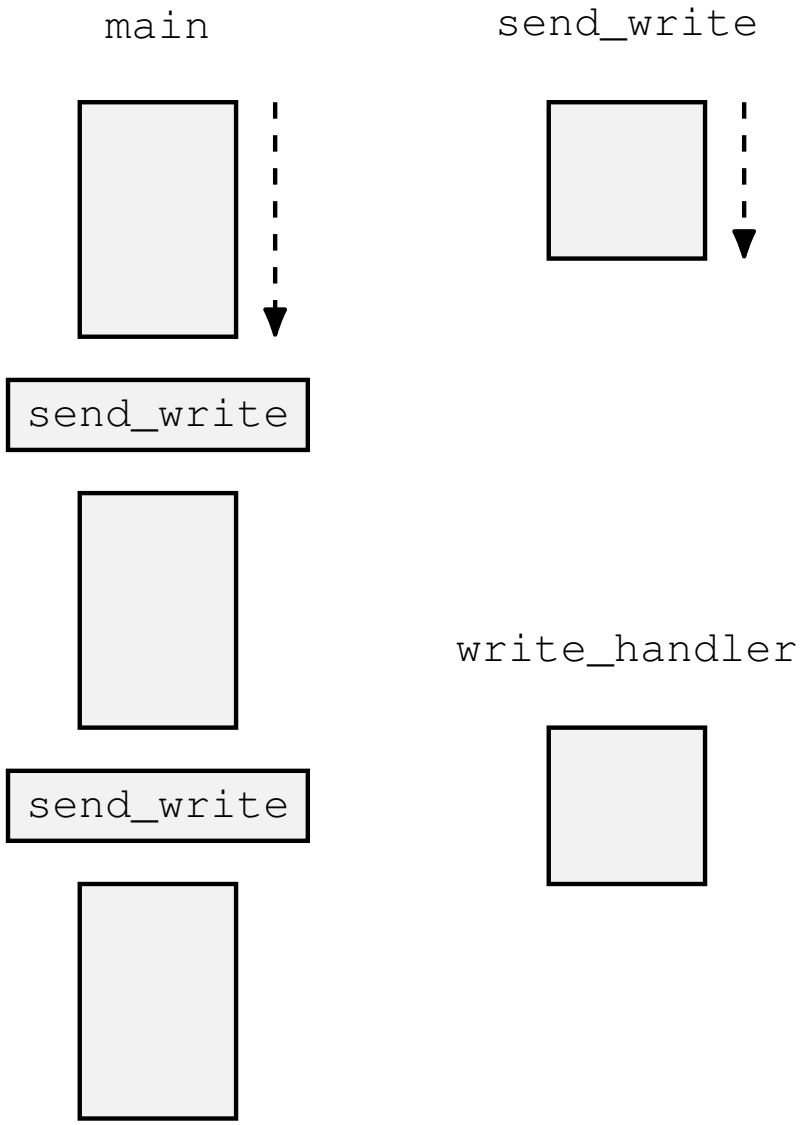

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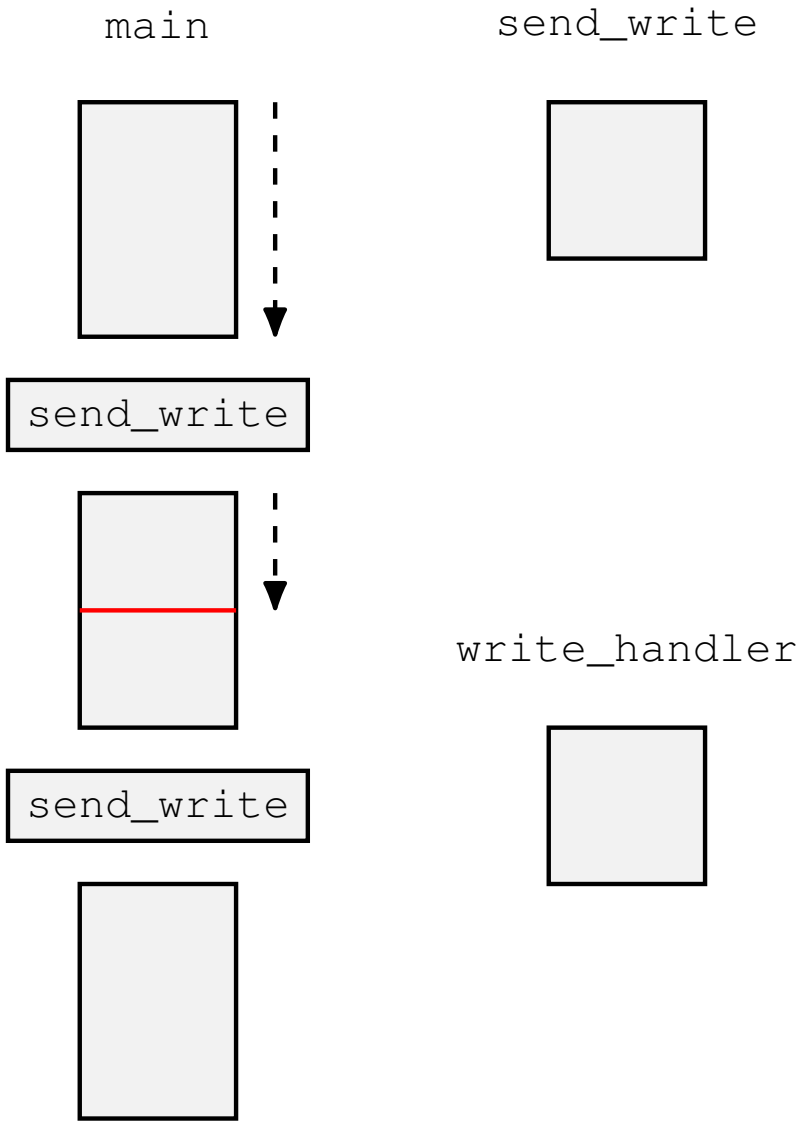

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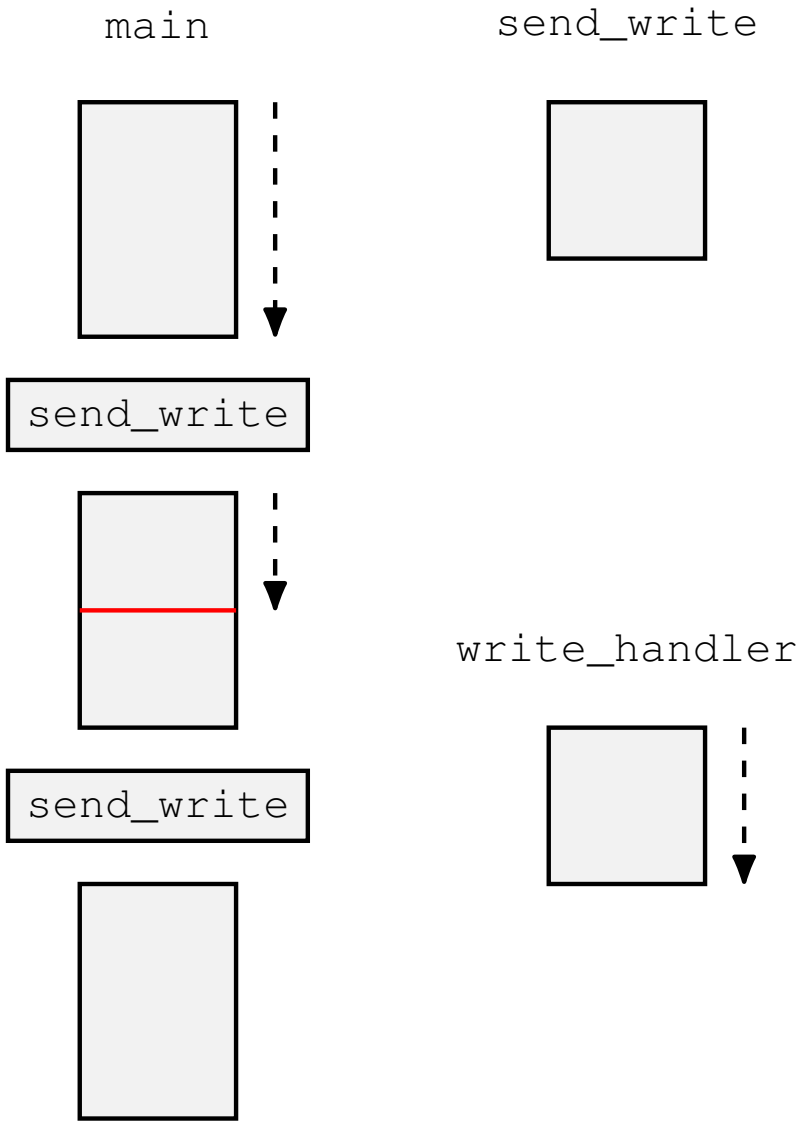

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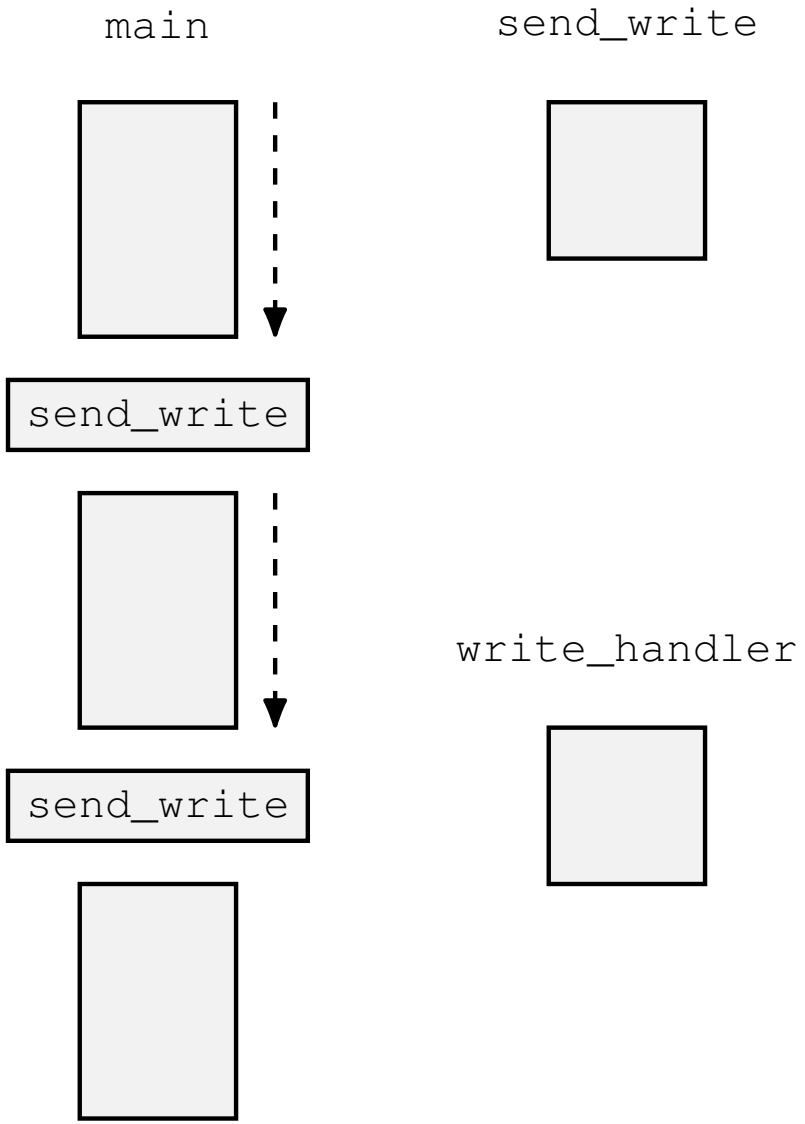

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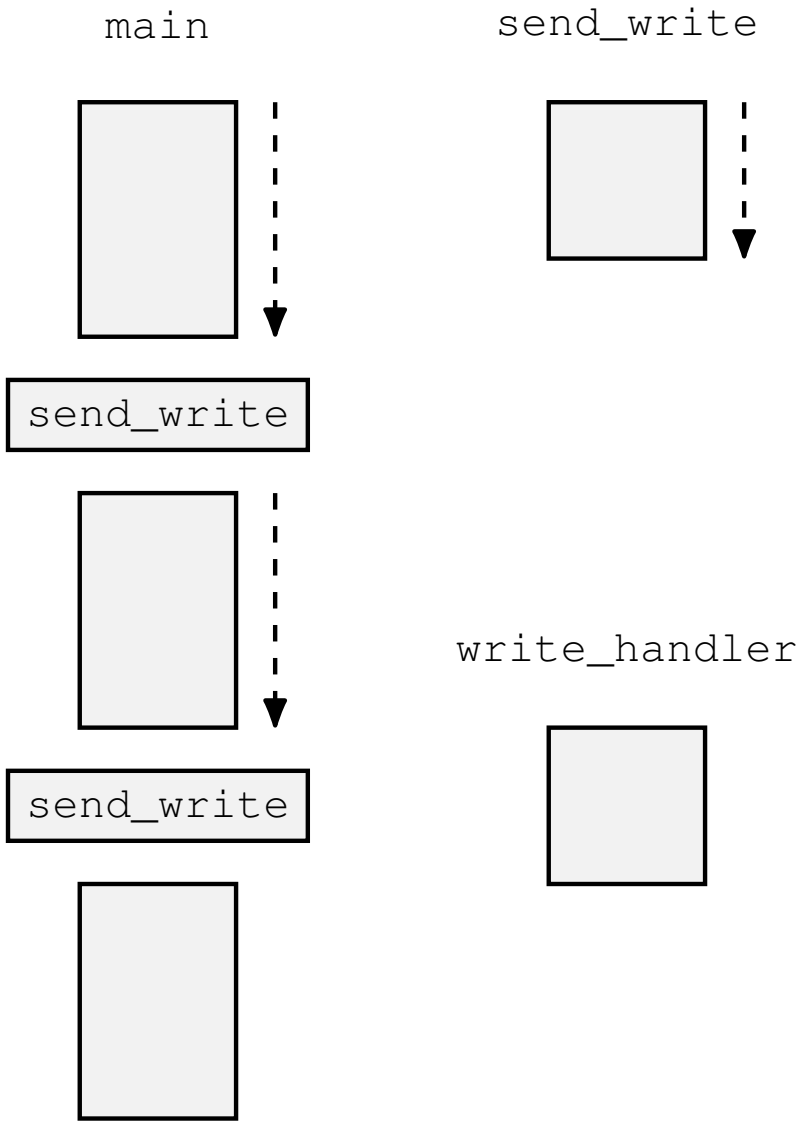

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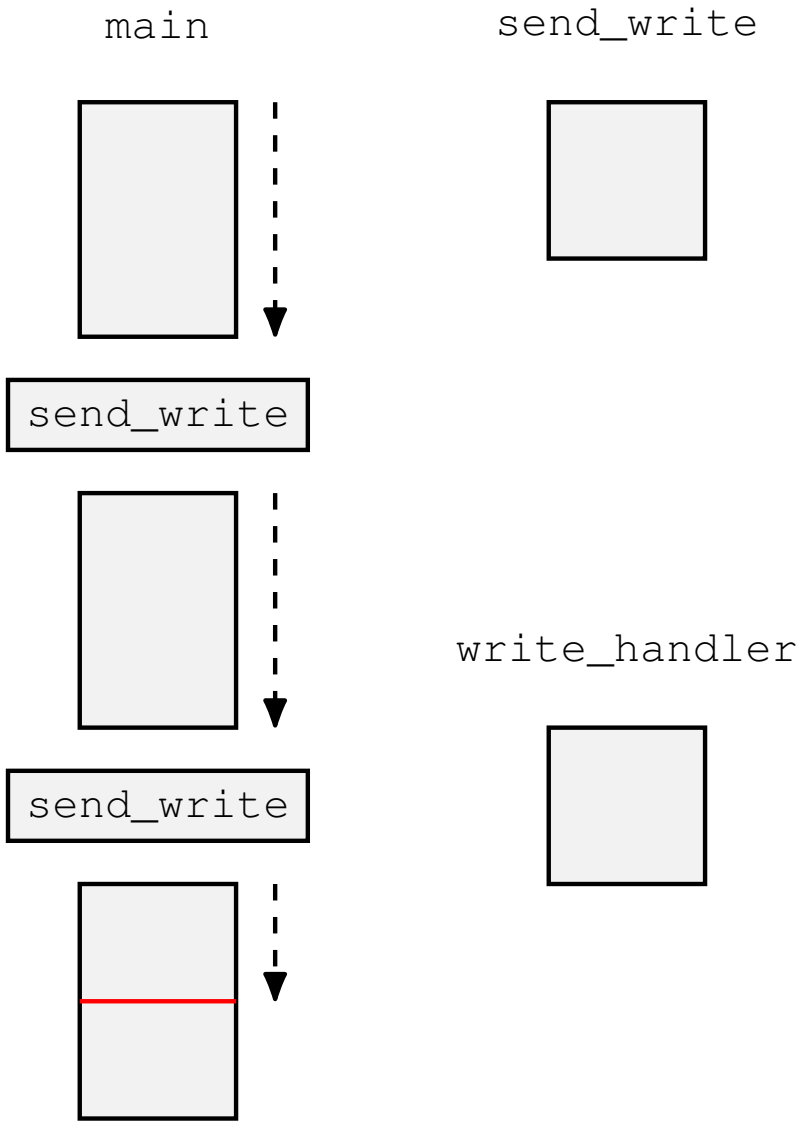

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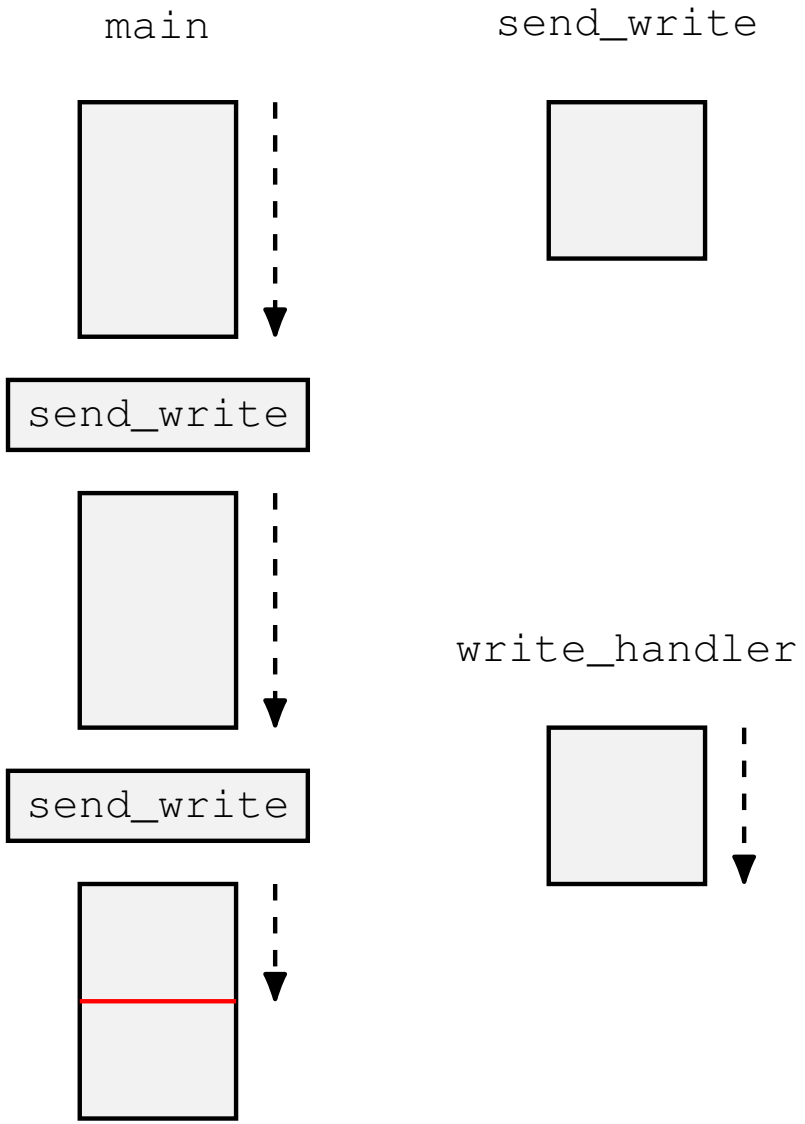

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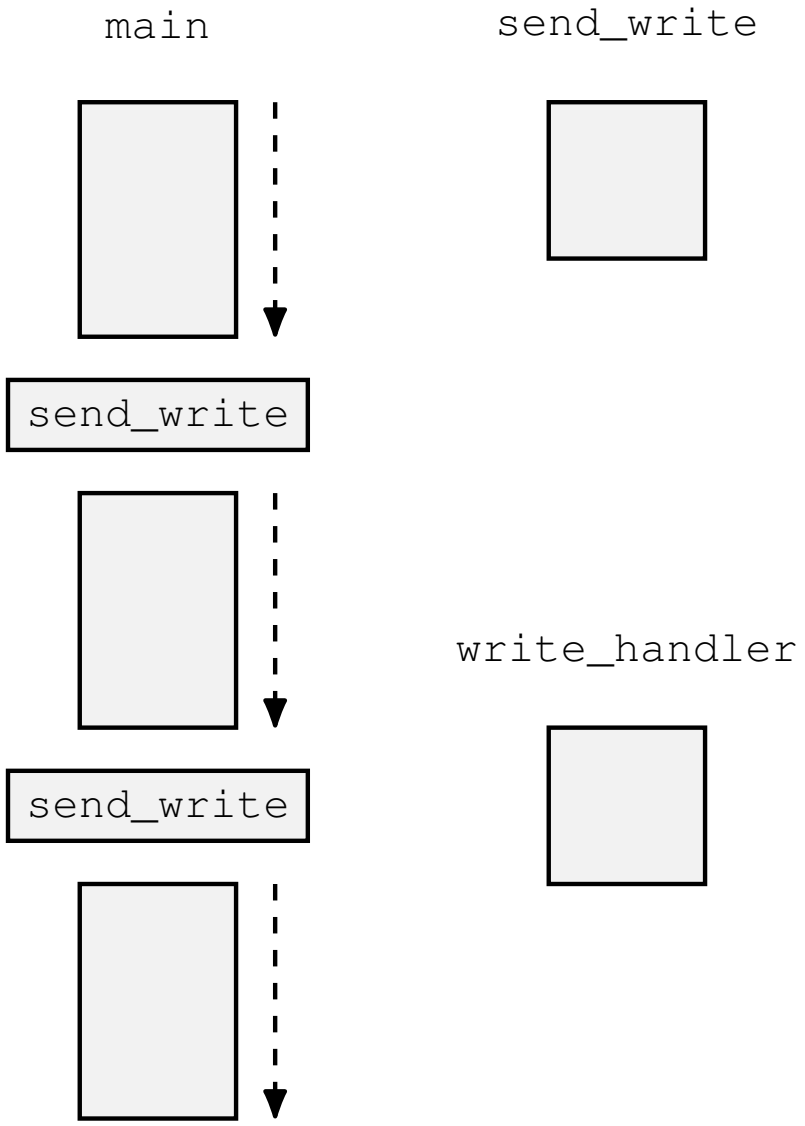

System calls

Entering the kernel by software request

System calls are how programs request services from the operating system.

Example (Typical system calls)

- Requesting memory
- Accessing files
- Running programs (processes)
- Accessing concurrency features

System calls

Entering the kernel by software request

We can distinguish between an API and systems calls.

- An API is a programming interface - typically a **library of functions that run in user space**, for example pthreads
- To provide the required features **an API may need to make system calls to access the required functionality**
- The relationship is *not* necessarily one-to-one - a **single API function may invoke zero, one or many system calls**
- Often programmers use less fussy terminology, and simply refer to the API functions as system calls

System calls

Entering the kernel by software request

Question

How can a system call allow a user process to run kernel space code?

System calls

Entering the kernel by software request

System call mechanisms (naive sketch)

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6. The interrupt is handled by kernel mode code, which calls a **system call service routine** which delivers the required functionality
7. The operating system continues running the calling code

System calls

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System call mechanisms (slightly less naive)

- The system call service routine **may not actually service the request immediately** - for example if it must wait on some resource such as IO
- The operating system **may not continue running the original caller**
- **System calls are the kernel's big chance to get work done for the benefit of everything running on the system**

System calls

Entering the kernel by software request

System call mechanisms (fussier details)

- Details vary by operating system
- Modern approaches may avoid interrupt based mechanisms and use other CPU support for efficiency reasons

The C Programming Language

Criteria for an OS Implementation Language

Question

Why would we choose such an old language like C for OS implementation?

```
1 #include <stdio.h>
2
3 int main() {
4   printf("Hello Operating Systems and Concurrency\n");
5 }
```

Performance

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- Bias toward performance over simplicity, elegance and maintainability.
- Cannot sacrifice correctness.

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- Ideally must be able to compile for many different hardware platforms.

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- Example - games cannot tolerate unpredictable delays slowing frame rates and responsiveness.
- Unpredictable behaviour such as garbage collection is inappropriate.

Recap

Take-Home Message

- Kernel mode code has more privileges than user code
- **Interrupts change the normal flow** of execution to invoke kernel code
- **System calls allow us to run kernel code** to access services of the operating system

Test your understanding

- What would be the advantages and disadvantages of a small kernel with a limited collection of system calls?
- What would be the advantages and disadvantages of a large kernel with a rich collection of system calls?
- How much harm can a bug in a user process cause?
- How much harm can a bug in the kernel cause?