# Processes & ECF

Science

Computer Science

CS 351: Systems Programming

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# Agenda

- Definition & OS responsibilities
- Exceptional control flow
  - synch vs. asynch exceptions
  - exception handling procedure

# §Definition & OS responsibilities

a **process** is a *program in execution* programs *describe* what we want done,

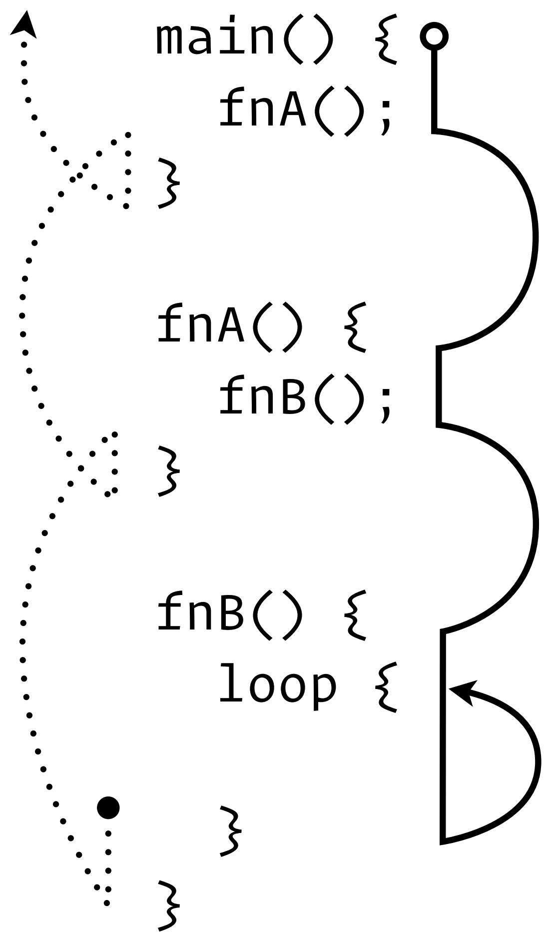
processes *carry out* what we want done

a process comprises ...

{ code (program)

+ runtime data (global, local, dynamic)

+ PC, SP, FP & other registers }




essential to program execution is *predictable, logical control flow*

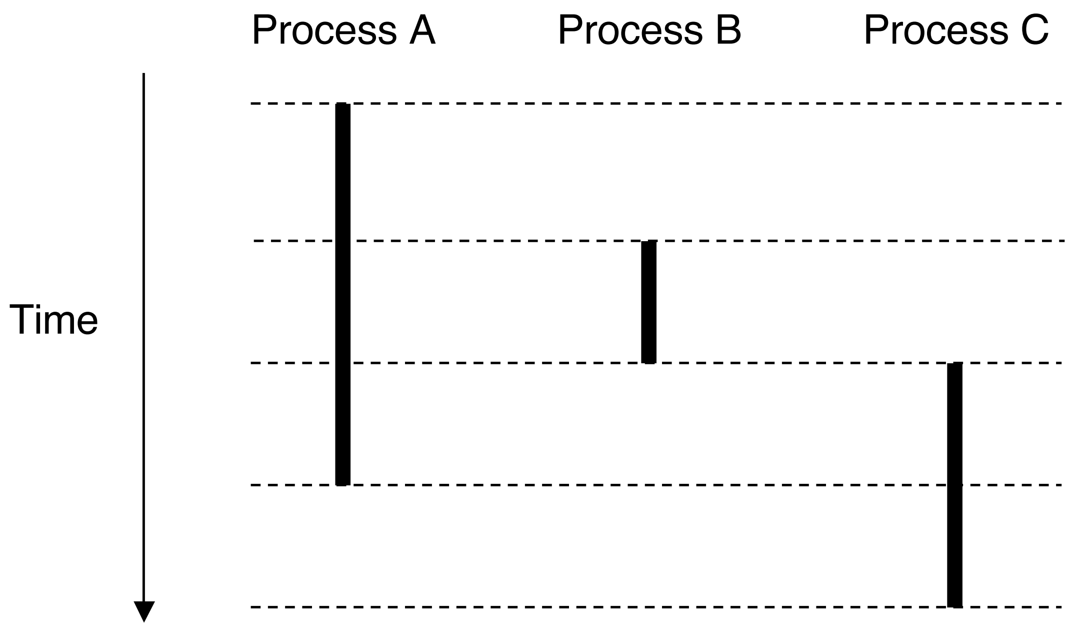
which requires that nothing disrupt the program mid-execution easiest way to guarantee this is for a process to "own" the CPU for its entire duration

... downsides?

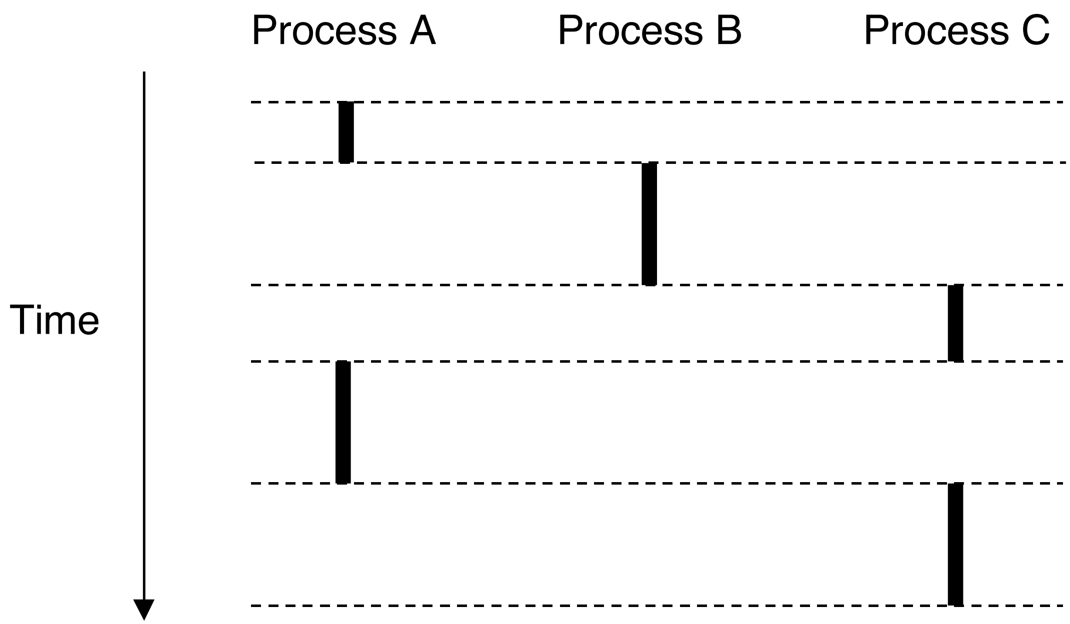
1. No multitasking!
2. A malicious (or badly written) program can “take over” the CPU forever
3. An idle process (e.g., waiting for input) will underutilize the CPU

the operating system presents each process with a simulated, *seamless logical control flow*

many of which can be taking place *concurrently* on one or more CPUs



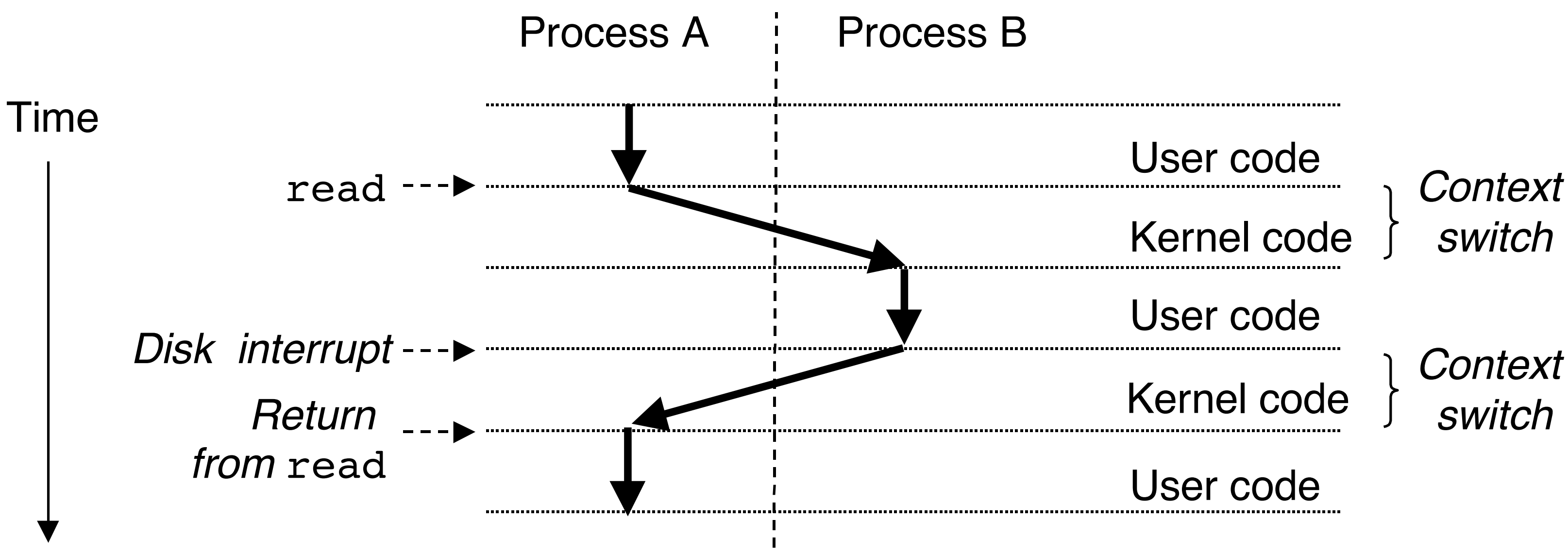

# Logical control flow




# Physical flow (1 CPU)

to do this, we need (1) a hardware mechanism to periodically interrupt the current process to load the OS, (2) an OS procedure that decides which processes to run, in what order, and (3) a routine for seamlessly transitioning between processes

(1) is the *periodic clock interrupt;*
(2) is the OS *scheduler;*
(3) is the *context switch*




Need new diagram that shows context switches triggered by the clock interrupt.

# Context switches

to implement scheduling and carry out context switches, the OS must maintain a wealth of *per-process metadata*

a process comprises ...

{ code (program)

+ runtime data (global, local, dynamic)

+ PC, SP, FP & other registers

+ "process control block" (*OS metadata)* }

a process comprises ...

{ code (program)

+ runtime data (global, local, dynamic)

+ PC, SP, FP & other registers

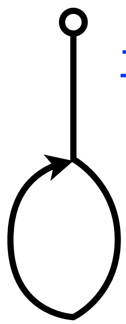
+ *e.g., PID, mem/CPU usage, pending syscalls* } context switches are *external* to a process's *logical* control flow (dictated by user program)

— part of *exceptional* control flow

# §Exceptional Control Flow

```c
int main() {
    while (1)
    {
        printf("hello world!\n");
    }
    return 0;
}
```

*logical c.f.*



```
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    {
        printf("hello world!\n");
    }
    return 0;
}
```

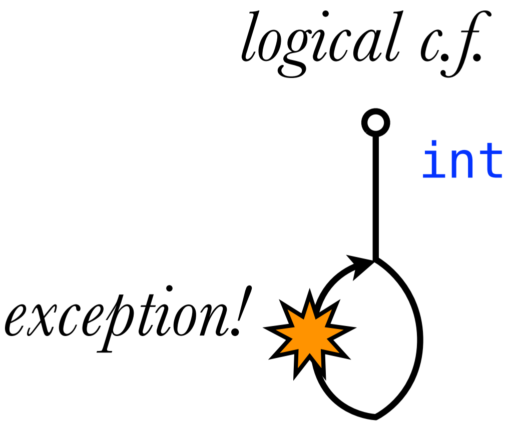


```c
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    {
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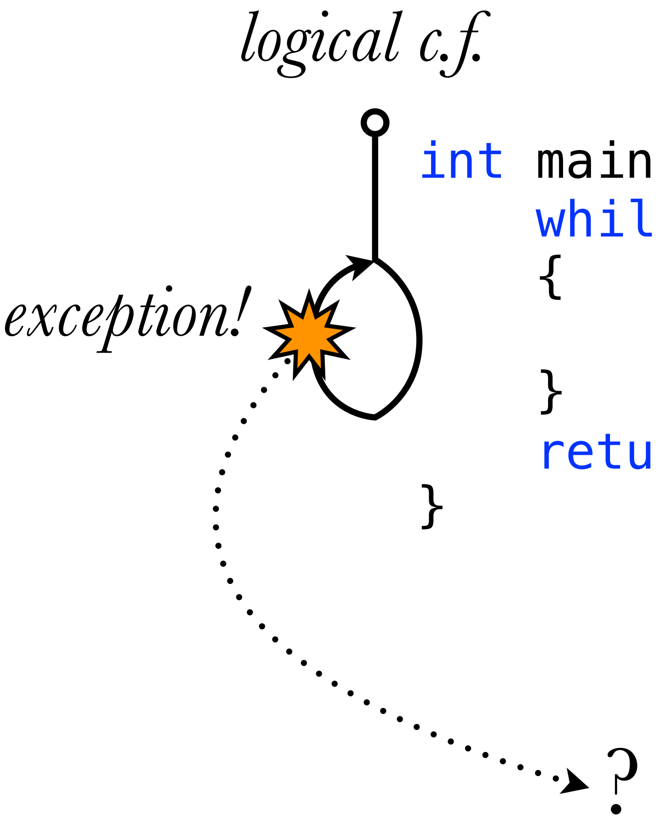
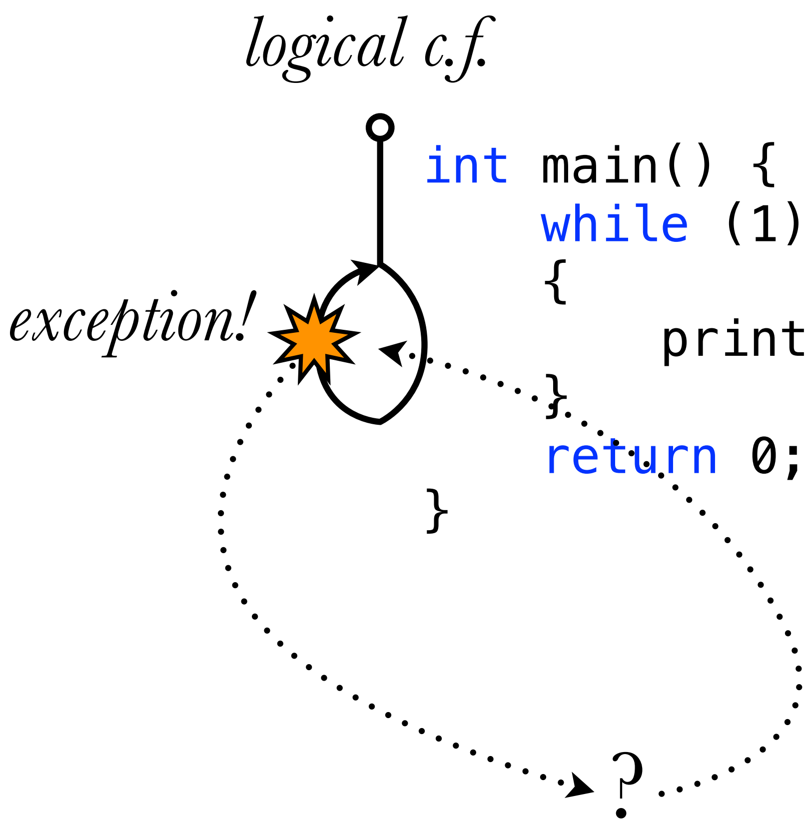



```c
int main() {
    while (1)
    {
        printf("hello world!\n");
    }
    return 0;
}
```




```c
int main() {
    while (1)
    {
        printf("hello world!\n");
    }
    return 0;
}
```

Two classes of exceptions:

I. synchronous

II. asynchronous

**I. synchronous exceptions** are caused by the *currently executing* instruction

3 subclasses of synchronous exceptions:

1. traps
2. faults
3. aborts

## 1. traps

traps are *intentionally* triggered by a process

e.g., to invoke a system call

```c
char *str = "hello world";
int len = strlen(str);
write(1, str, len);
```

```asm
mov   edx, len
mov   ecx, str
mov   ebx, 1
mov   eax, 4   ; syscall #4
int   0x80     ; trap to OS
```

return from trap (if it happens) resumes execution at the next logical instruction

## 2. faults

faults are usually *unintentional*, and may be recoverable or irrecoverable

e.g., segmentation fault, protection fault, page fault, div-by-zero often, return from fault will result in *retrying* the faulting instruction

— esp. if the handler "fixes" the problem

## 3. aborts

aborts are *unintentional* and *irrecoverable*

i.e., abort = program/OS termination

e.g., memory ECC error

**II. asynchronous exceptions** are caused by events *external to* the current instruction

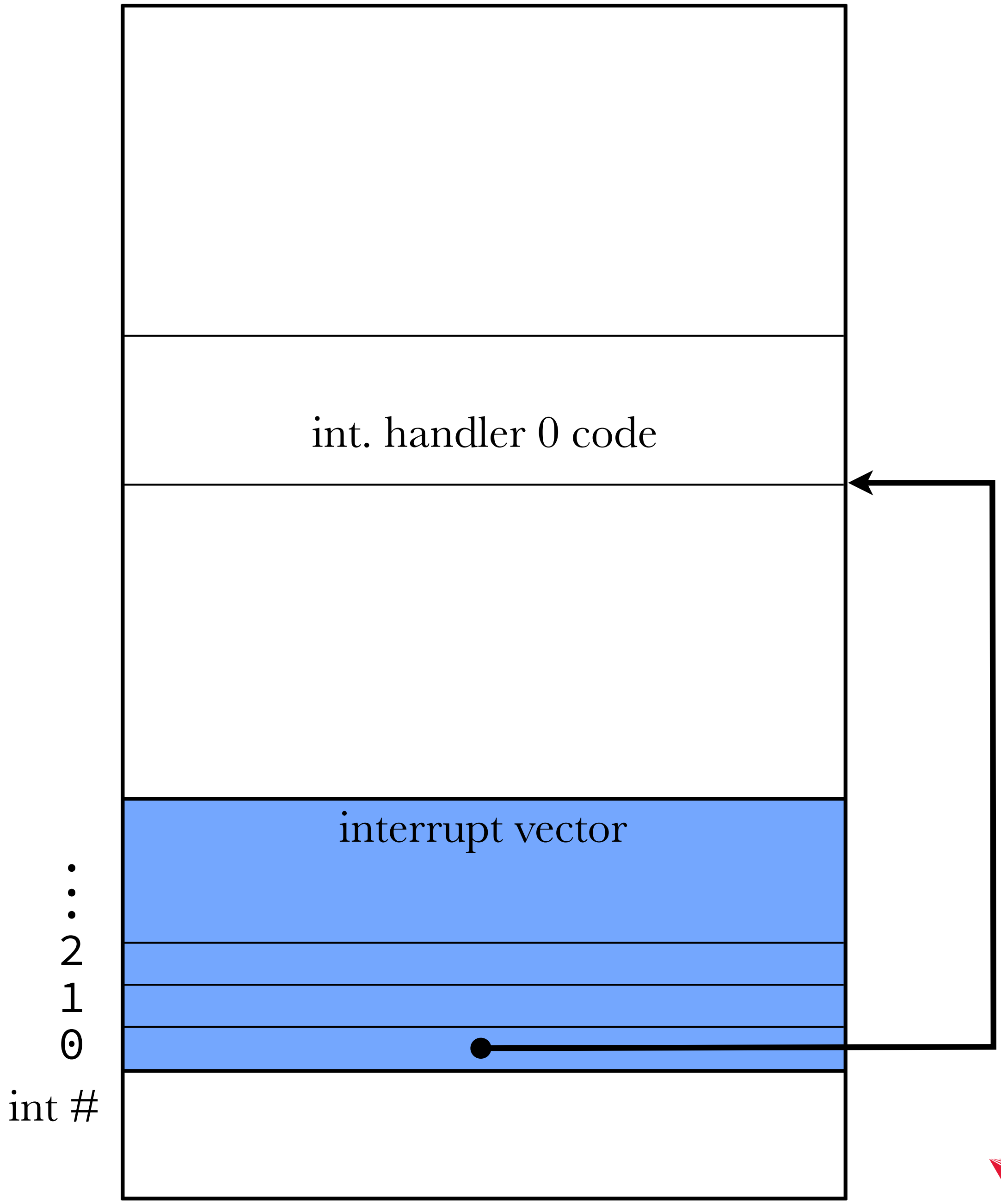
```c
int main() {
    while (1) {
        printf("hello world!\n");
    }
    return 0;
}
```

```
hello world!
hello world!
hello world!
hello world!
^C
$
```

hardware initiated asynchronous exceptions are known as *interrupts* e.g., ctrl-C, ctrl-alt-del, power switch interrupts are associated with specific processor (hardware) pins

- checked after every CPU cycle
- associated with interrupt handlers

# (system) memory

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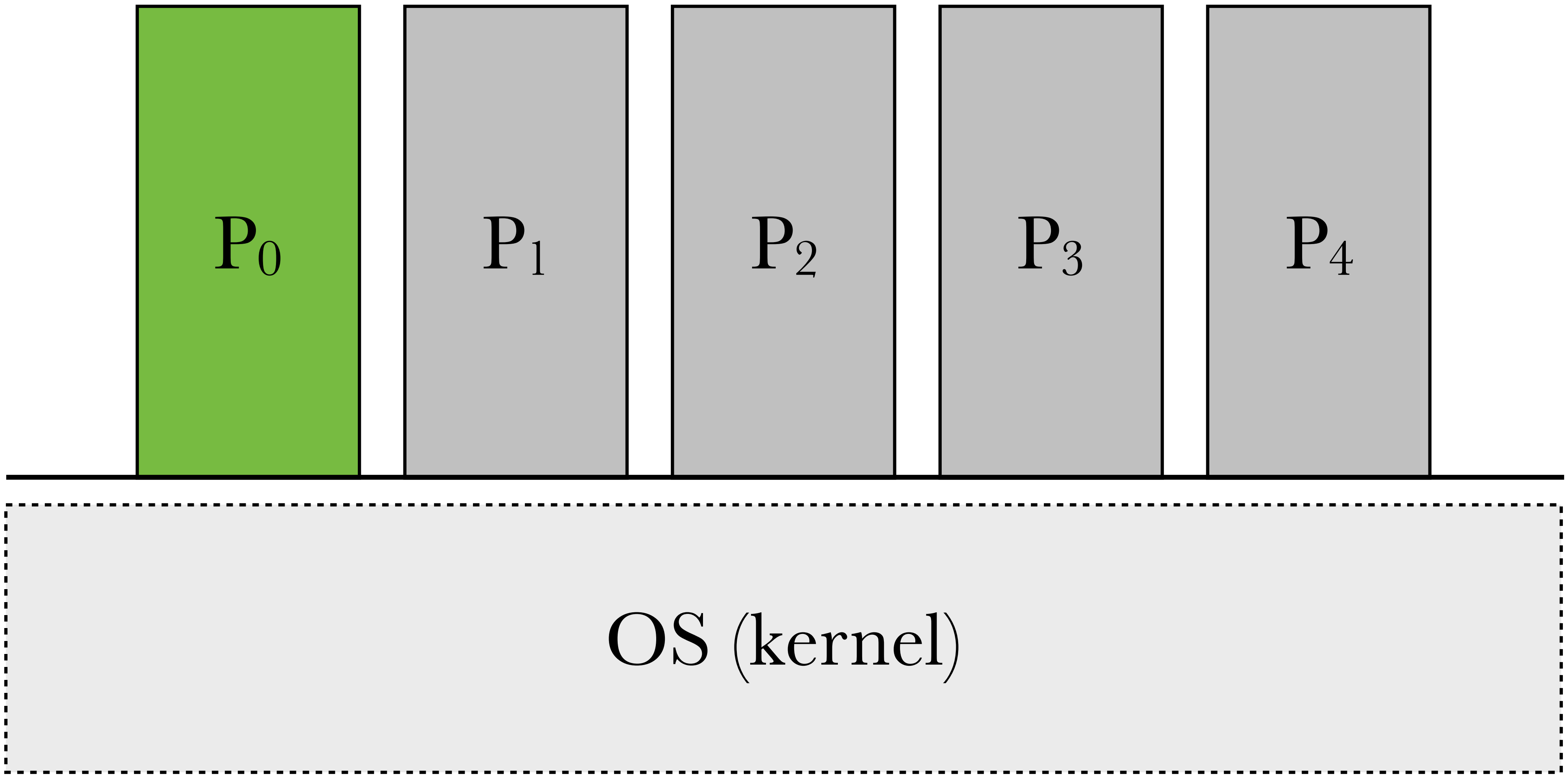
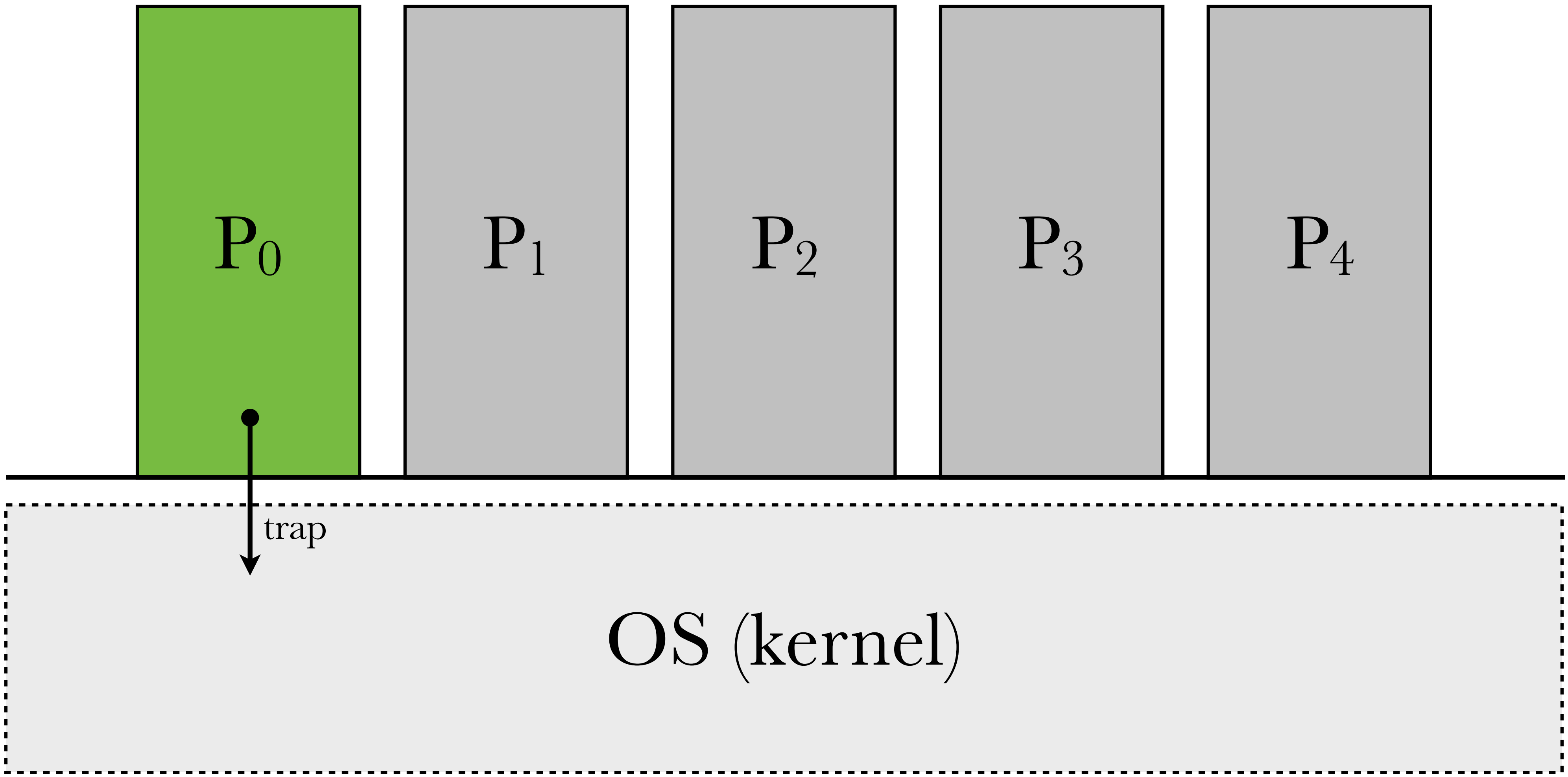
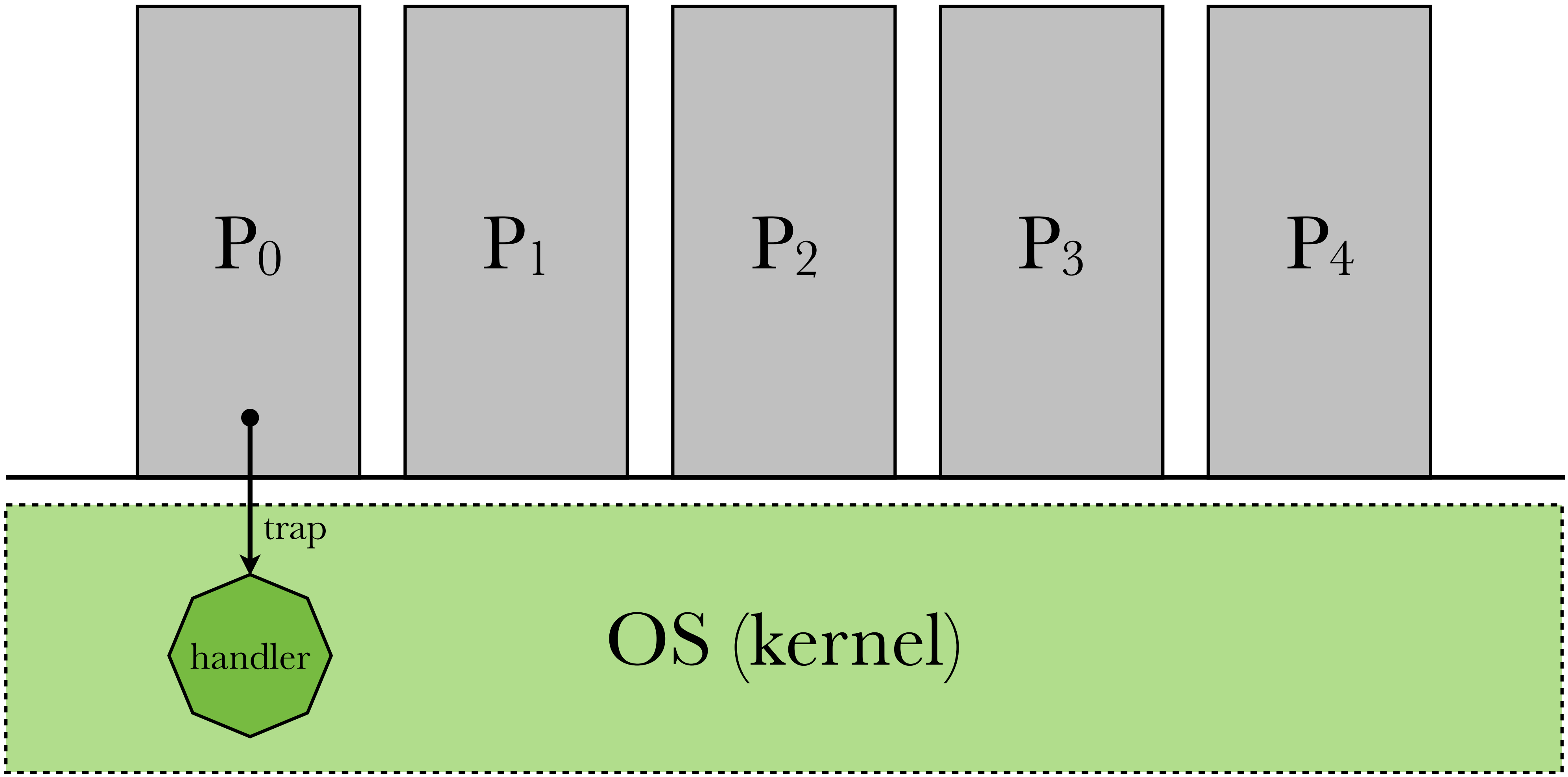
interrupt procedure (typical)

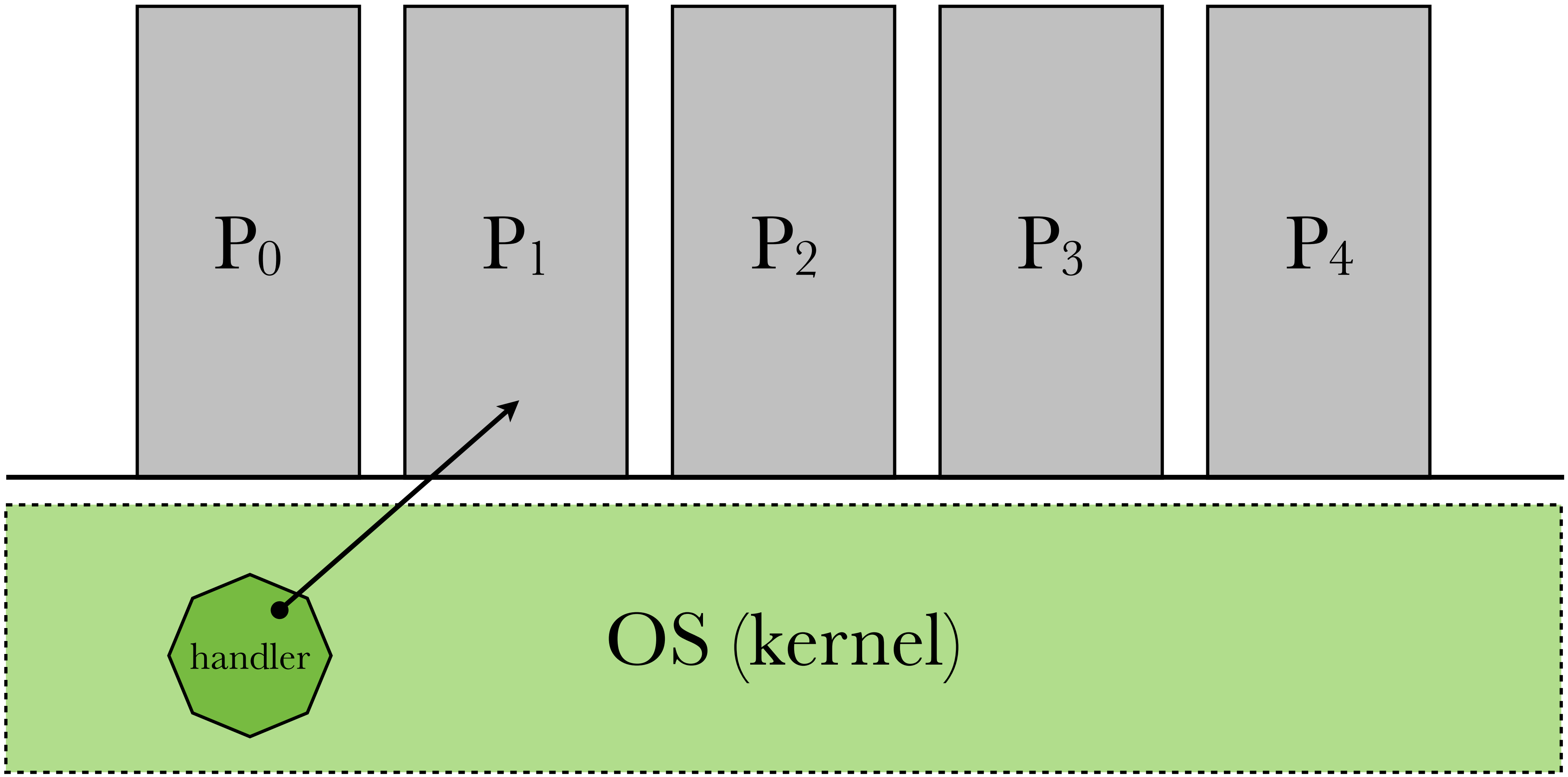
- save context (e.g., user process)
- load OS context
- execute handler
- load context (for …?)
- return

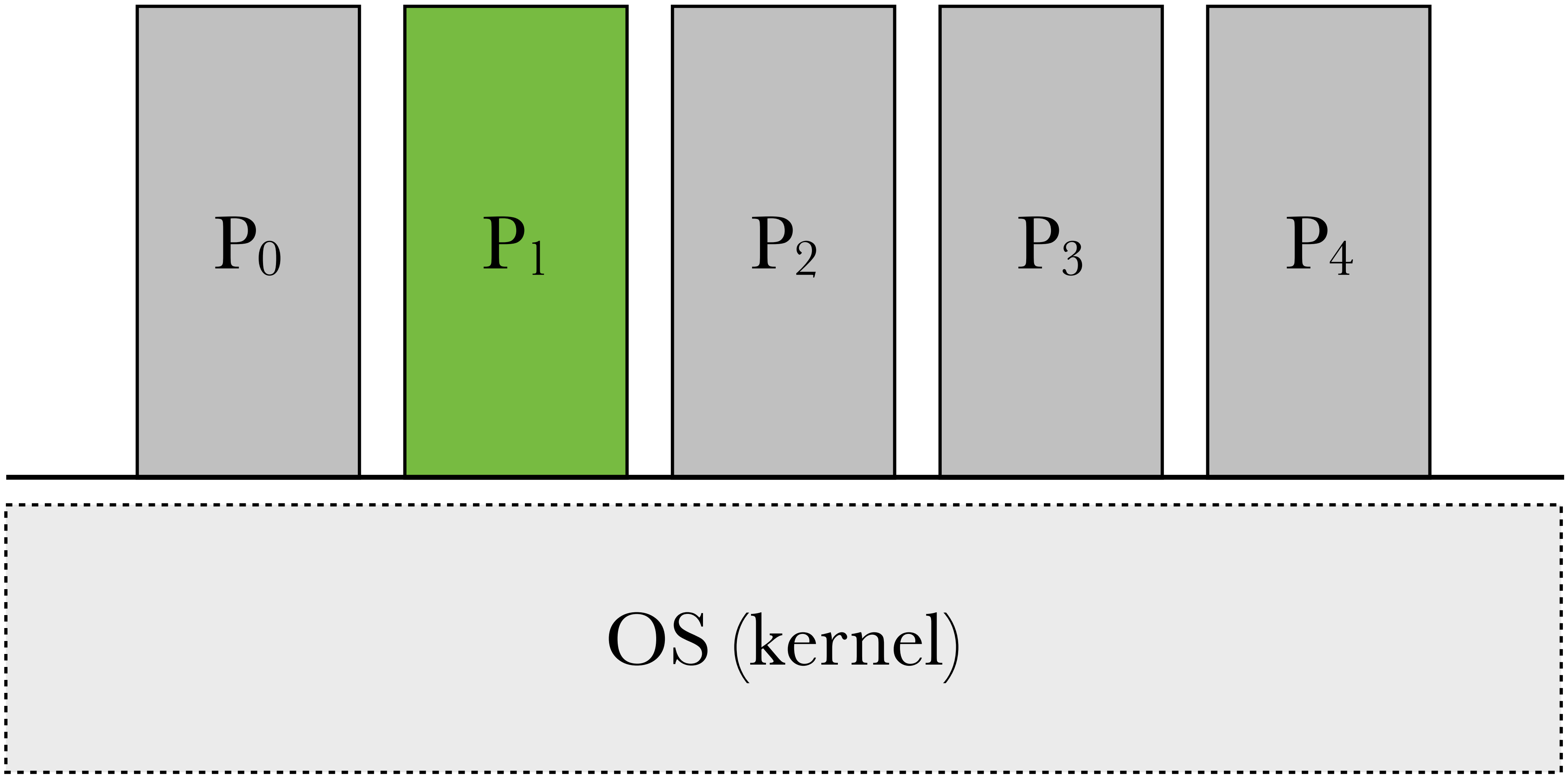
important: after switching context to the OS (for exception handling), there is *no guarantee if/when* a process will be switched back in!

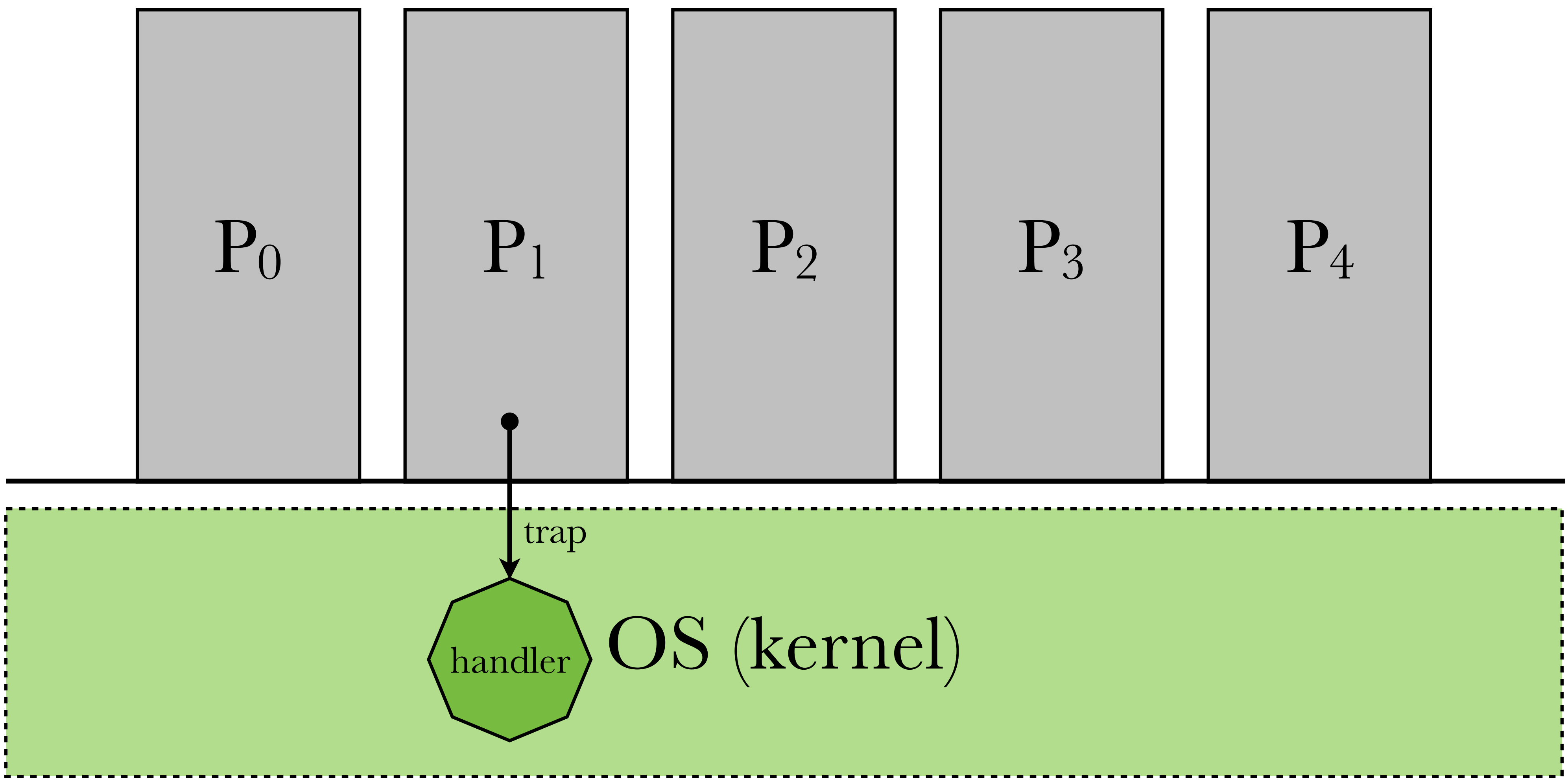

P0
P1
P2
P3
P4
OS (kernel)


P0
P1
P2
P3
P4
trap
OS (kernel)


$P_0$
$P_1$
$P_2$
$P_3$
$P_4$
trap
handler
OS (kernel)


$P_0$
$P_1$
$P_2$
$P_3$
$P_4$
handler
OS (kernel)


$P_0$
$P_1$
$P_2$
$P_3$
$P_4$
OS (kernel)


$P_0$
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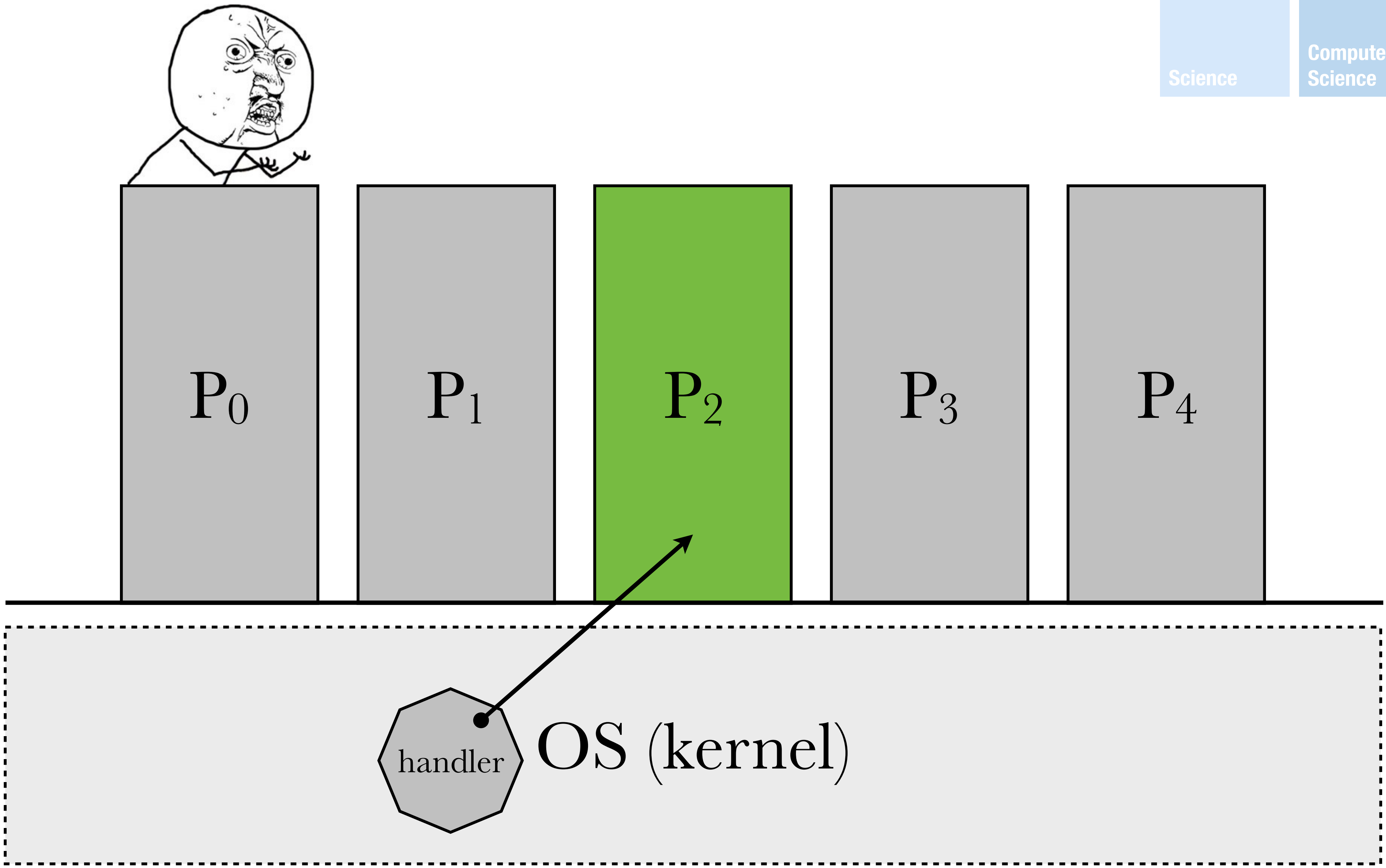
trap
handler
OS (kernel)


P0
P1
P2
P3
P4
handler
OS (kernel)

switching context to the kernel is potentially *very expensive*

— but the only way to invoke system calls and access I/O moral (to be reinforced ad nauseum):

use system calls (traps) sparingly!