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# Solving Mutual Exclusion (1)

Concurrency and Parallelism — 2018-19

Master in Computer Science

(Mestrado Integrado em Eng. Informática)

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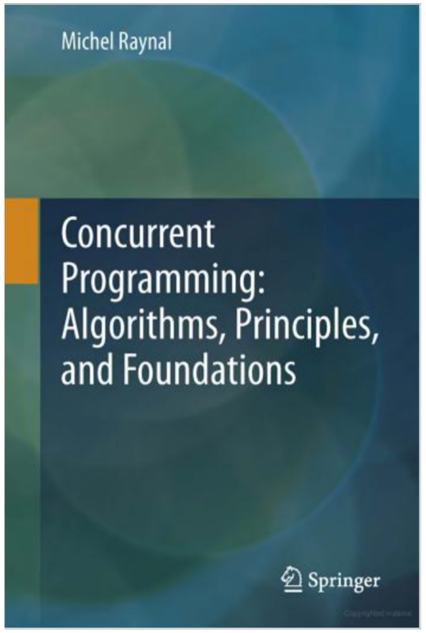
## Summary

- **Solving Mutual Exclusion**
  - Mutex based on atomic read-write registers
  - Concurrency-abortable operation

- **Reading list:**
  - **Chapter 2** of the book
    Raynal M.;
    **Concurrent Programming: Algorithms, Principles, and Foundations;**
    Springer-Verlag Berlin Heidelberg (2013);
    ISBN: 978-3-642-32026-2

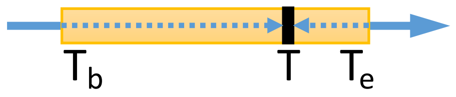

Michel Raynal
Concurrent Programming: Algorithms, Principles, and Foundations
Springer

# Mutex Based on Atomic Read/Write Registers

- A *register R* can be accessed by two base operations:
- ***R*.read()**, which returns the value of *R* (also denoted **x** ← ***R*** where x is a local variable of the invoking process); and
- ***R*.write(v)**, which writes a new value into *R* (also denoted ***R*** ← **v**, where v is the value to be written into *R*).

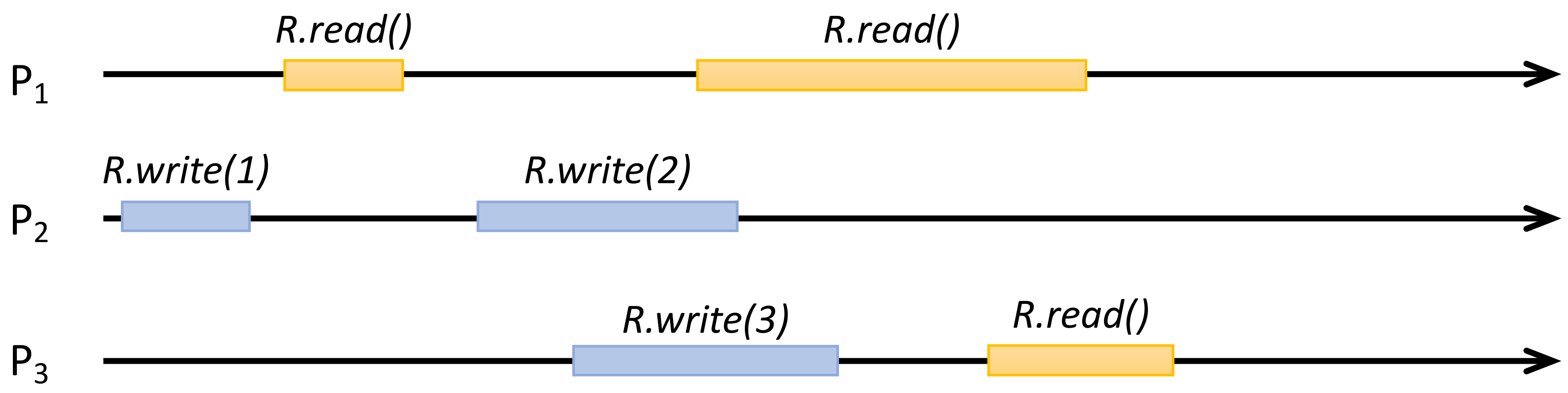
# Mutex Based on Atomic Read/Write Registers

- An *atomic* shared register satisfies the following properties:
- Each invocation **op** of a **read** or **write** operation:
  - Appears as if it was executed at a single point *T(op)* of the time line;
  - *T(op)* is such that $T_b(op) \leq T(op) \leq T_e(op)$, where $T_b(op)$ and $T_e(op)$ denote the time at which the operation *op* started and finished, respectively;
  - For any two operation invocations *op1* and *op2*: $(op1 \neq op2) \Rightarrow T(op1) \neq T(op2)$.

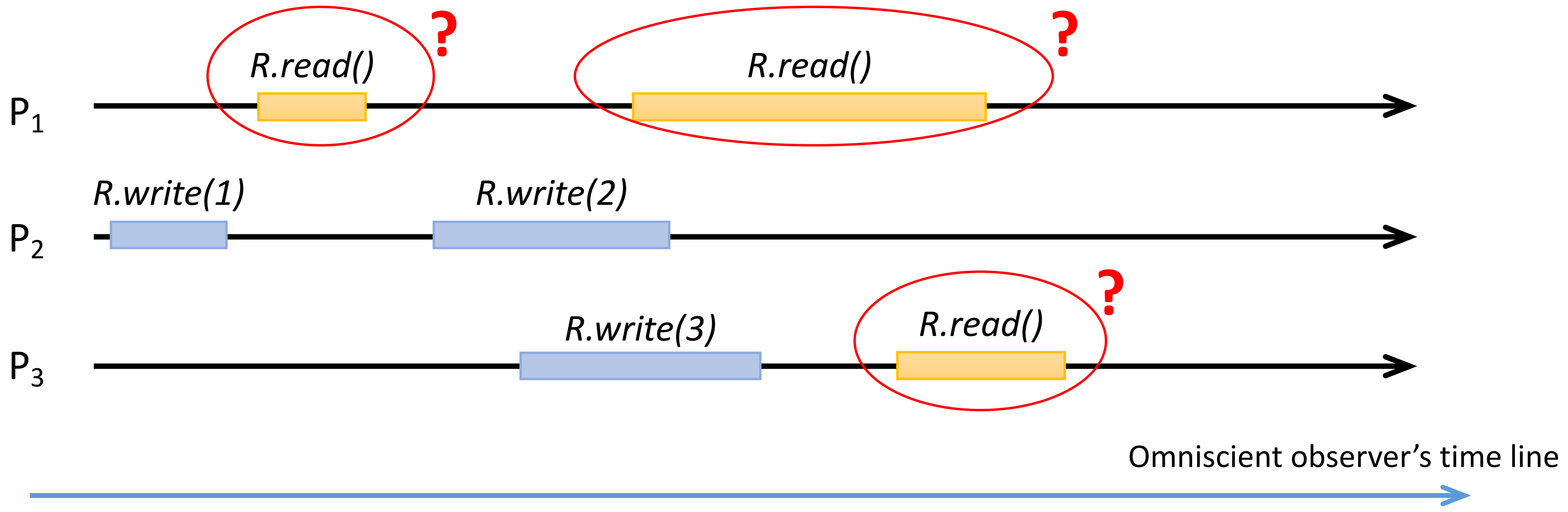


- Each read invocation:
  - Returns the value written by the closest preceding write invocation in the sequence defined by the *T(…)* instants associated with the operation invocations (or the initial value of the register if there is no preceding write operation).

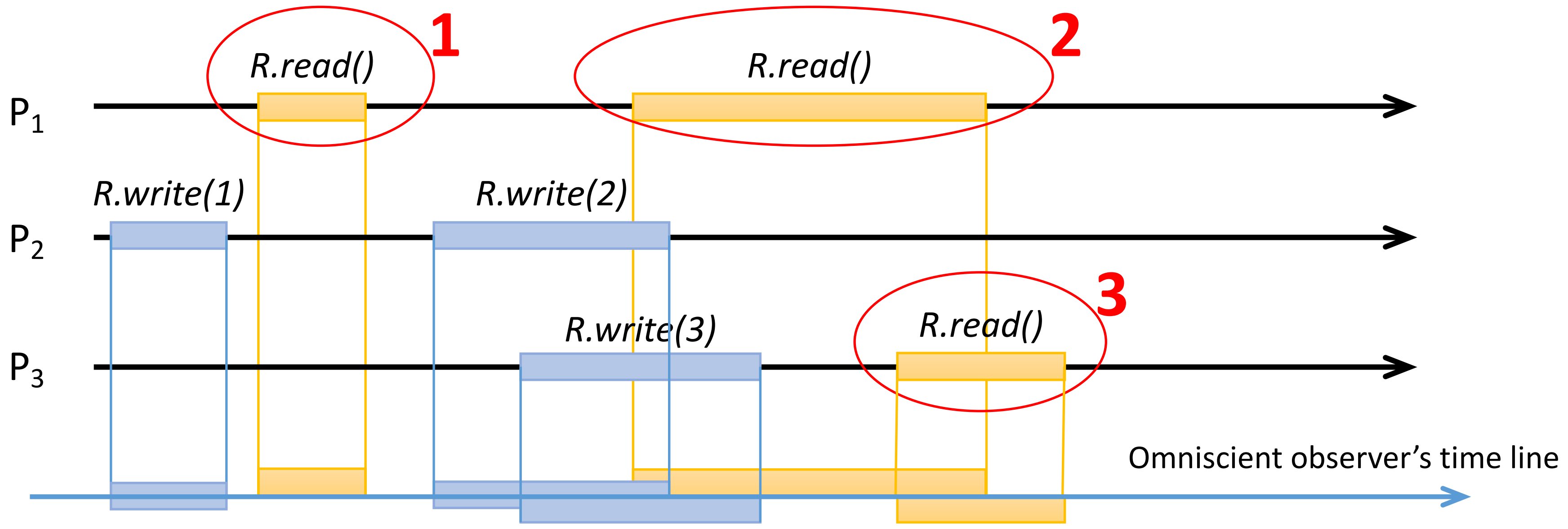
# Mutex Based on Atomic Read/Write Registers



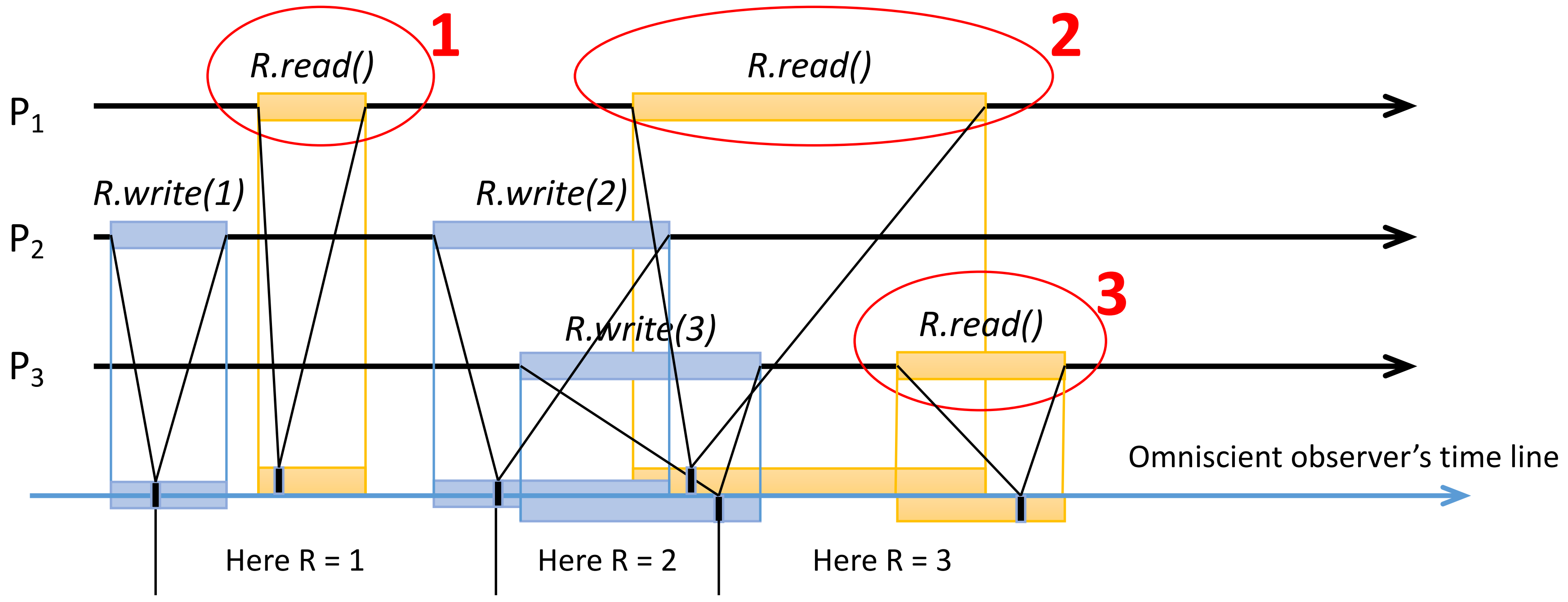
# Mutex Based on Atomic Read/Write Registers



# Mutex Based on Atomic Read/Write Registers



# Mutex Based on Atomic Read/Write Registers



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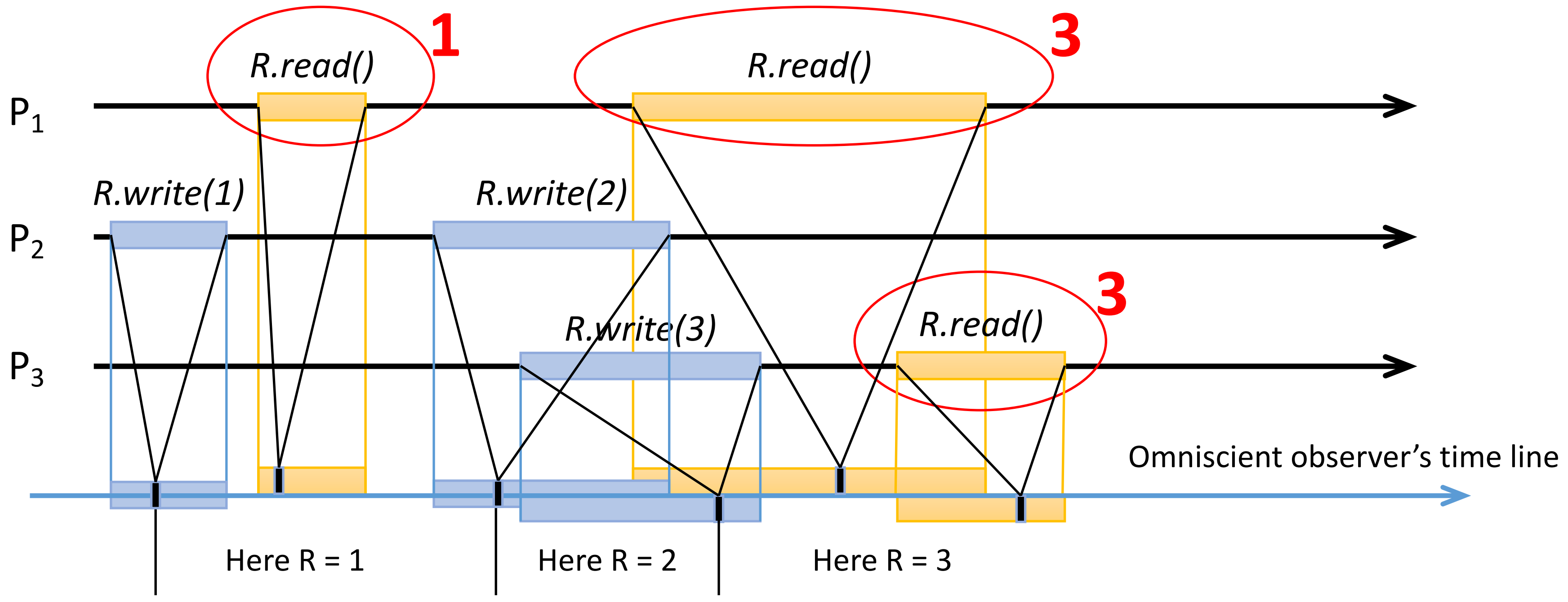

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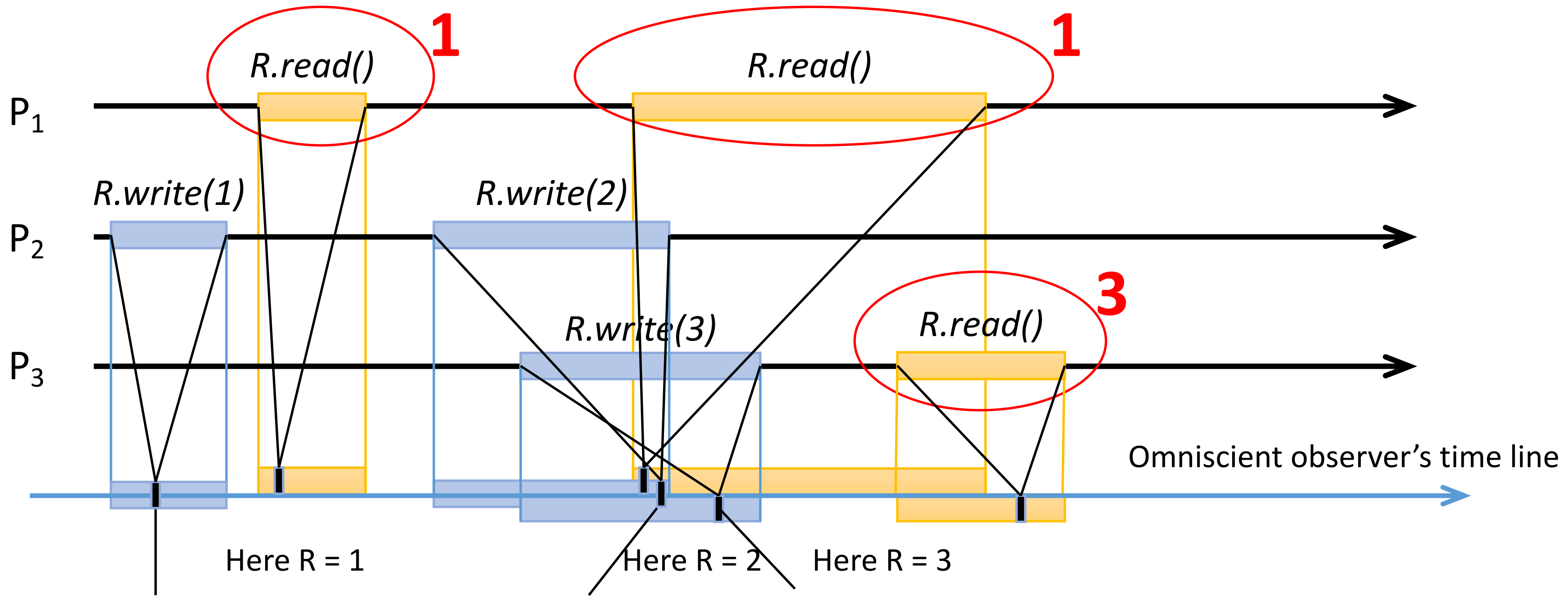

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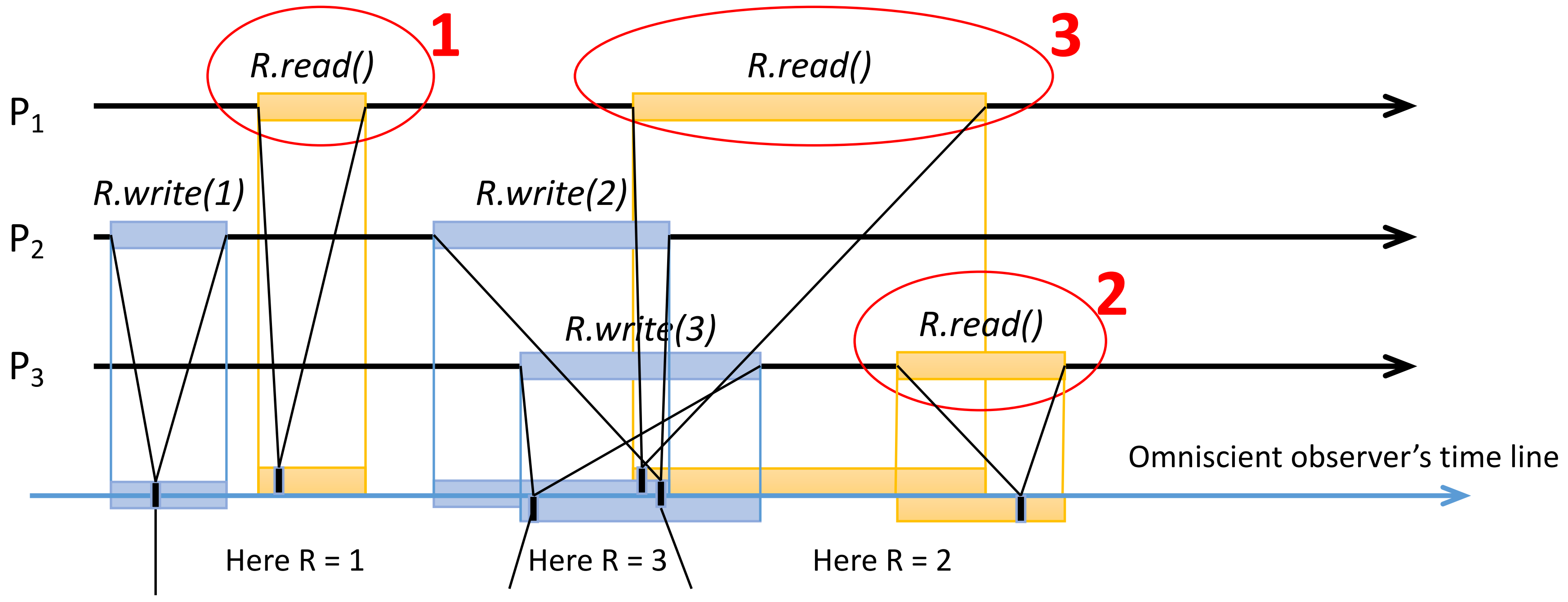
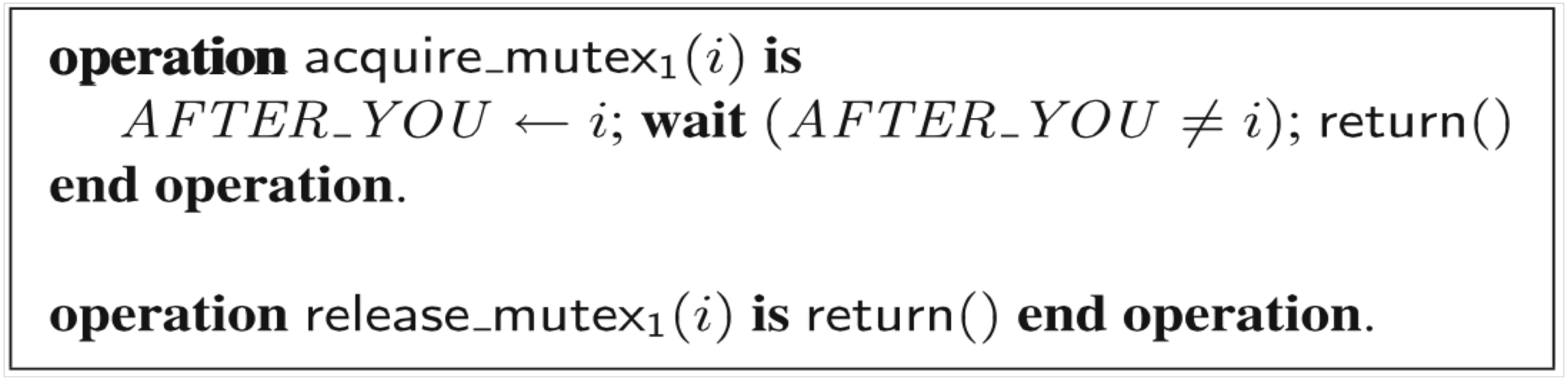


# Mutex for Two Processes: An Incremental Construction



```
operation acquire_mutex$_1(i)$ is
    $AFTER\_YOU \leftarrow i$; wait $(AFTER\_YOU \neq i)$; return()
end operation.

operation release_mutex$_1(i)$ is return() end operation.
```

*G.L. Peterson (1981)*

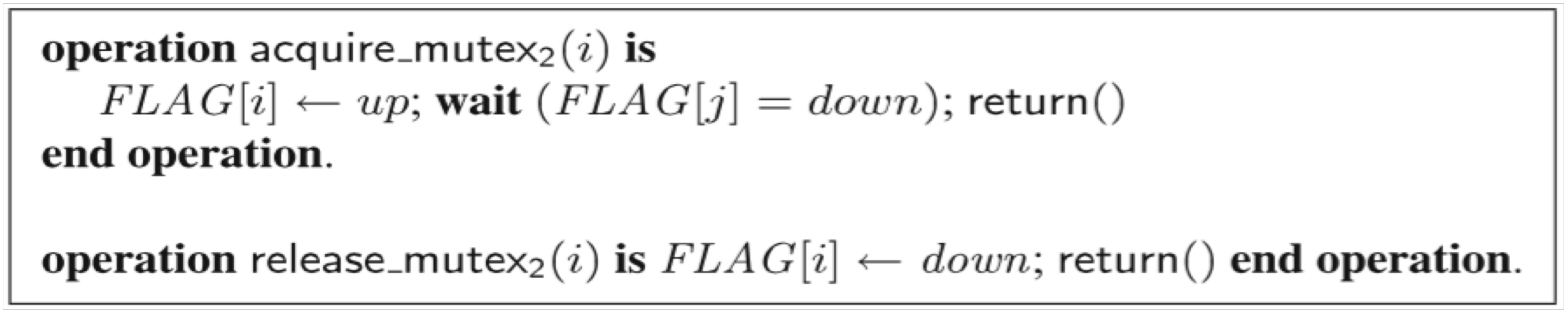
Must have contention to have progress

May cause deadlock (by starvation)

✓ mutual exclusion

X progress

# Mutex for Two Processes: An Incremental Construction



```
operation acquire_mutex_2(i) is
    $FLAG[i] \leftarrow up$; wait $(FLAG[j] = down)$; return()
end operation.

operation release_mutex_2(i) is $FLAG[i] \leftarrow down$; return() end operation.
```

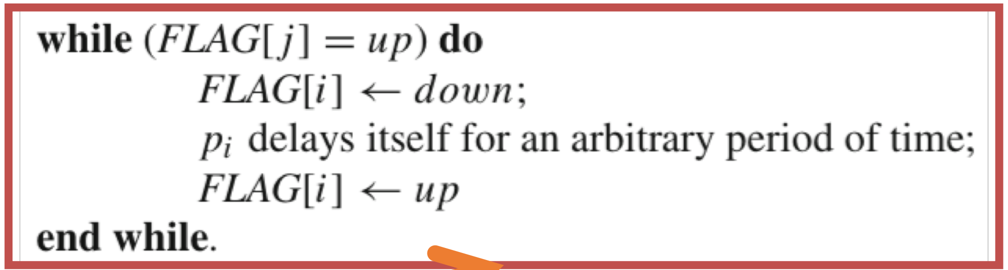
May cause deadlock

*G.L. Peterson (1981)*

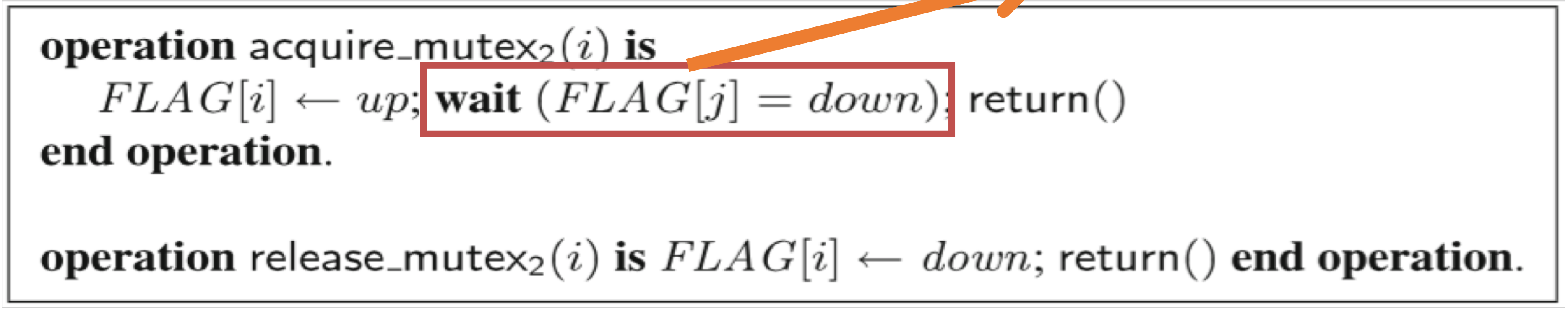
✓ mutual exclusion
X progress

# Mutex for Two Processes: An Incremental Construction

?



```
while ($FLAG[j] = up$) do
        $FLAG[i] \leftarrow down$;
        $p_i$ delays itself for an arbitrary period of time;
        $FLAG[i] \leftarrow up$
end while.
```



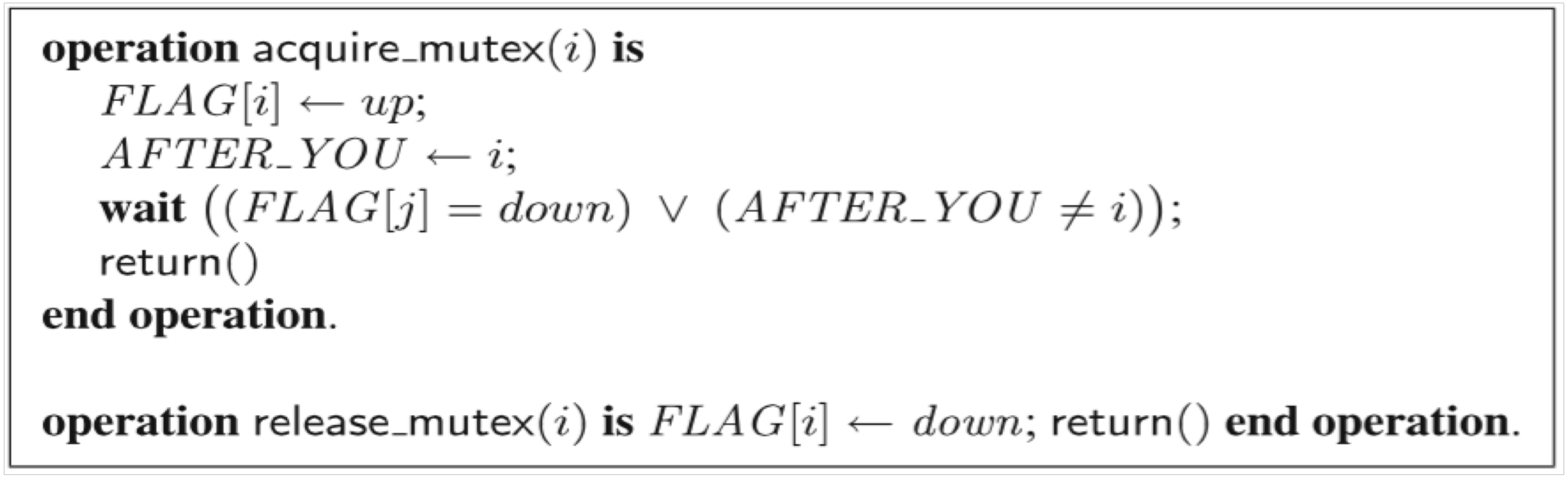
```
operation acquire_mutex$_2(i)$ is
    $FLAG[i] \leftarrow up$; wait ($FLAG[j] = down$); return()
end operation.

operation release_mutex$_2(i)$ is $FLAG[i] \leftarrow down$; return() end operation.
```

May cause livelock

*G.L. Peterson (1981)*

✓ mutual exclusion
X progress

# Mutex for Two Processes: An Incremental Construction



```
operation acquire_mutex($i$) is
    $FLAG[i] \leftarrow up$;
    $AFTER\_YOU \leftarrow i$;
    wait $((FLAG[j] = down) \vee (AFTER\_YOU \neq i))$;
    return()
end operation.

operation release_mutex($i$) is $FLAG[i] \leftarrow down$; return() end operation.
```

Only works for two processes!
Can we make it work for more?

*G.L. Peterson (1981)*

✓ mutual exclusion
✓ progress

# Mutex for n Processes: Generalizing the Previous Two-Process Algorithm

```
operation acquire_mutex($i$) is
 (1)  for $\ell$ from $1$ to $(n-1)$ do
 (2)       $FLAG\_LEVEL[i] \leftarrow \ell$;
 (3)       $AFTER\_YOU[\ell] \leftarrow i$;
 (4)       wait  $(\forall k \neq i: FLAG\_LEVEL[k] < \ell) \vee (AFTER\_YOU[\ell] \neq i)$
 (5)  end for;
 (6)  return()
end operation.

operation release_mutex($i$) is $FLAG\_LEVEL[i] \leftarrow 0$; return() end operation.
```

✓mutual exclusion
✓progress

*G.L. Peterson (1981)*

$p_i$ is allowed to progress to level 'l+1' if, from its point of view,

- Either all the other processes are at a lower level (i.e., $\forall k \neq i$:*FLAG_LEVEL* [*k*] < l).
- Or it was not the last one entering level 'l' (i.e., *AFTER_YOU*[l] ≠ *i*).

# The END