COL380

Introduction to
Parallel & Distributed Programming

Agenda

- Understanding memory consistency

Memory Model

@ atom
Address space

Memory Model

- Register size?
- Limit on the number of readers and writers?
- Asynchronous reads and writes
  - ➡ Global knowledge of ‘time?’

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Register

✳ What is the value read? (Correctness)

“Most recent Write”

Memory Model

- Register size?
- Limit on the number of readers and writers?
- Asynchronous reads and writes
    - ➡ Global knowledge of 'time?'

✴ What is the value read? (Correctness)

- Increasing power ⇒ reducing performance

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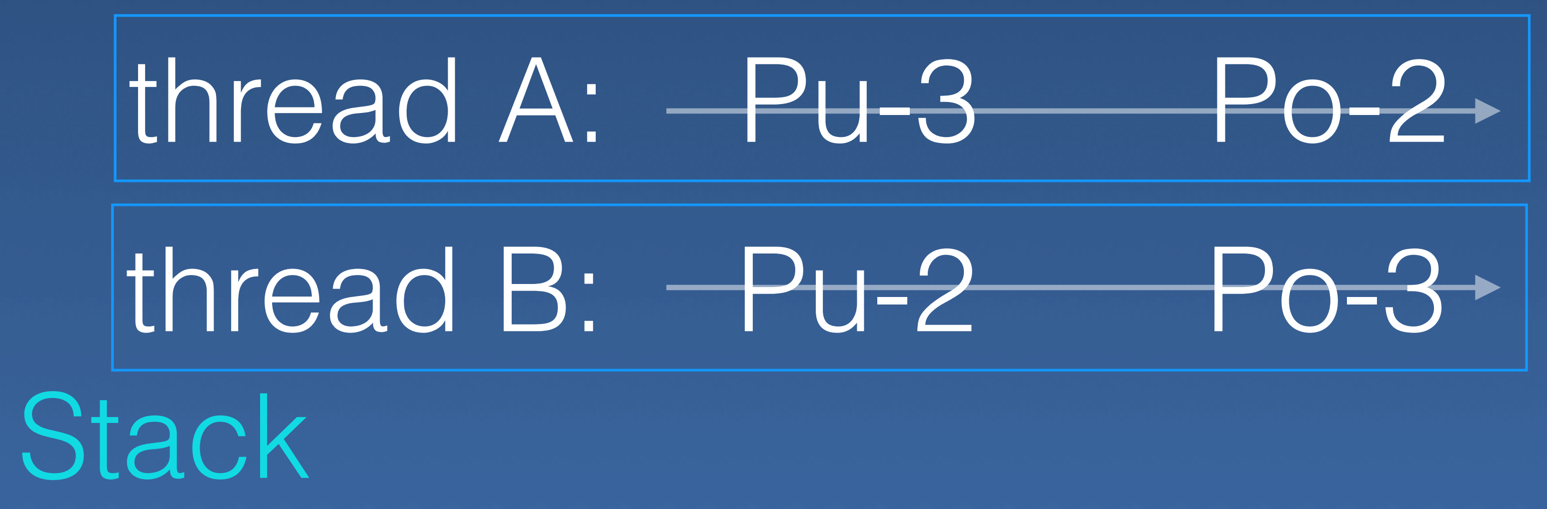
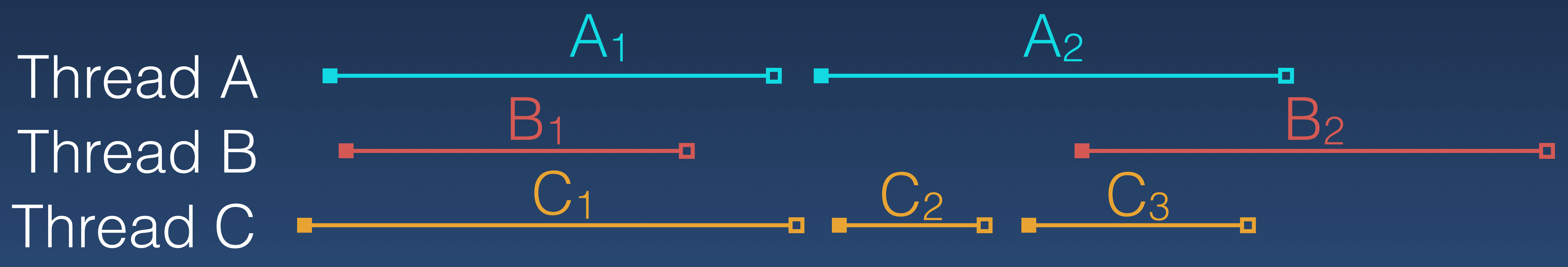
Same ideas apply to higher level data structures



Linearizable

- Operations appear to take effect at some instant
  - ➡ between their start and end
  - ➡ If there is no overlap, ordering is well defined



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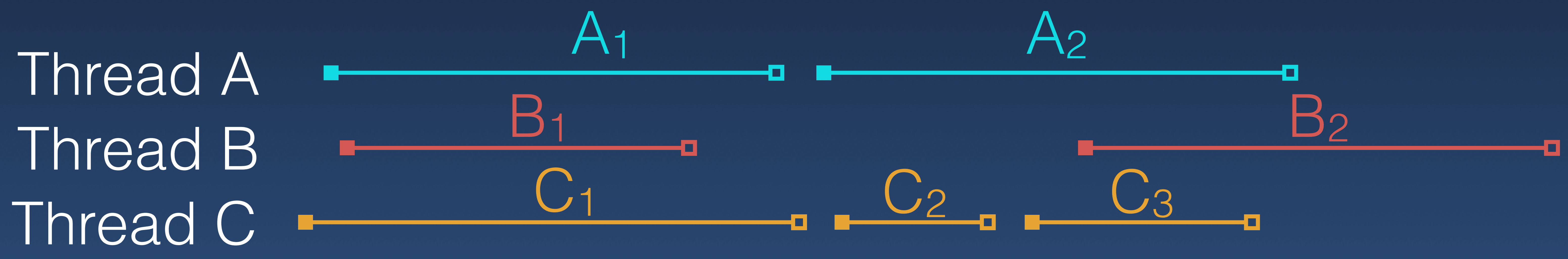

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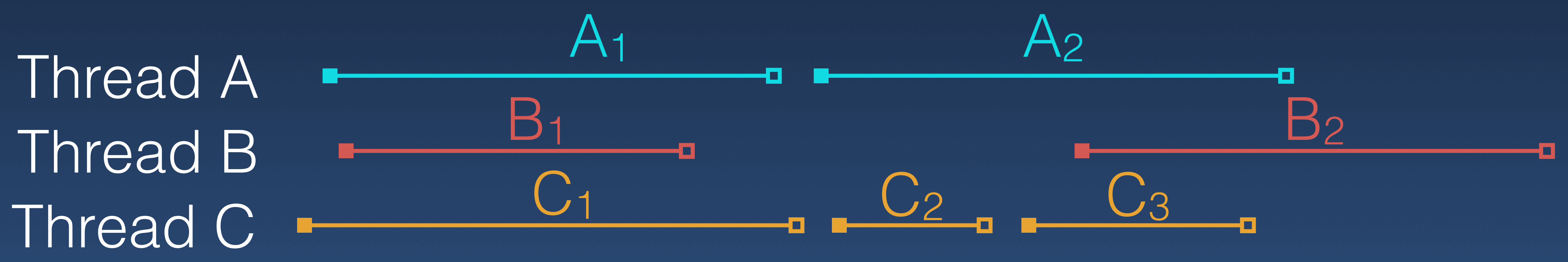

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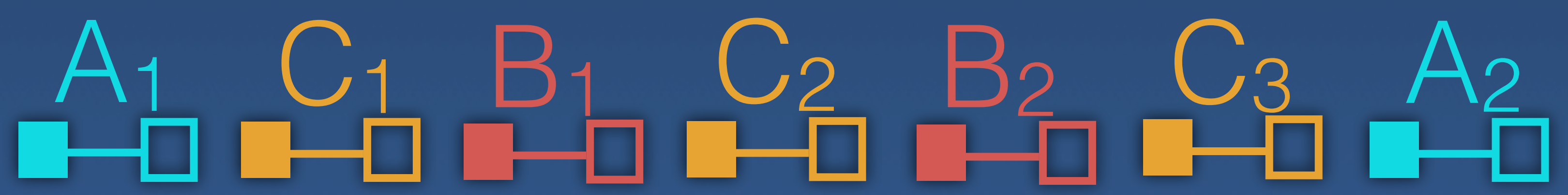

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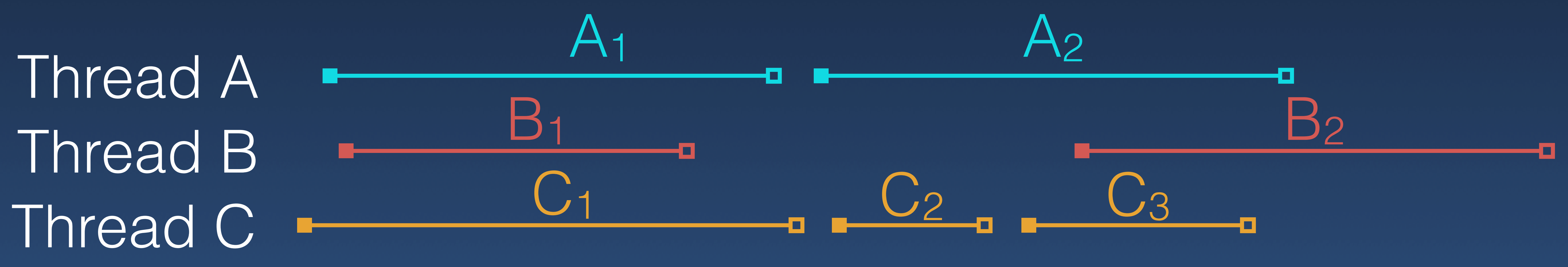

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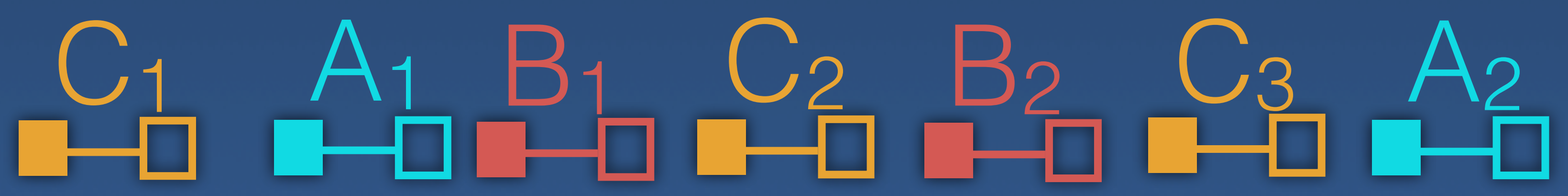

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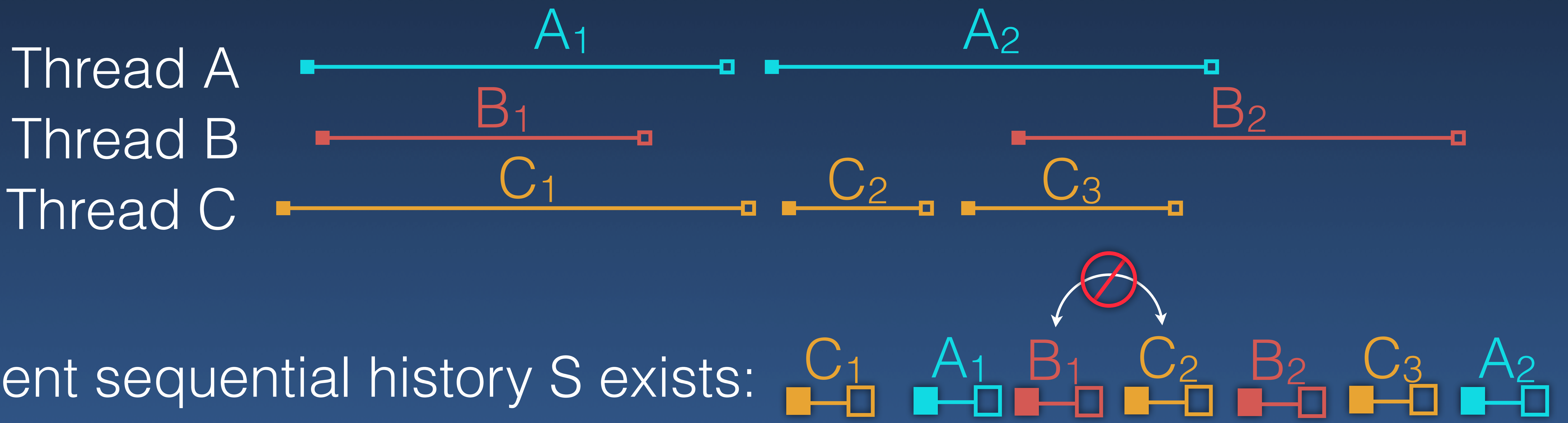
Thread A
Thread B
Thread C
A_1
A_2
B_1
B_2
C_1
C_2
C_3
Equivalent sequential history S exists:
C_1 A_1 B_1 C_2 B_2 C_3 A_2

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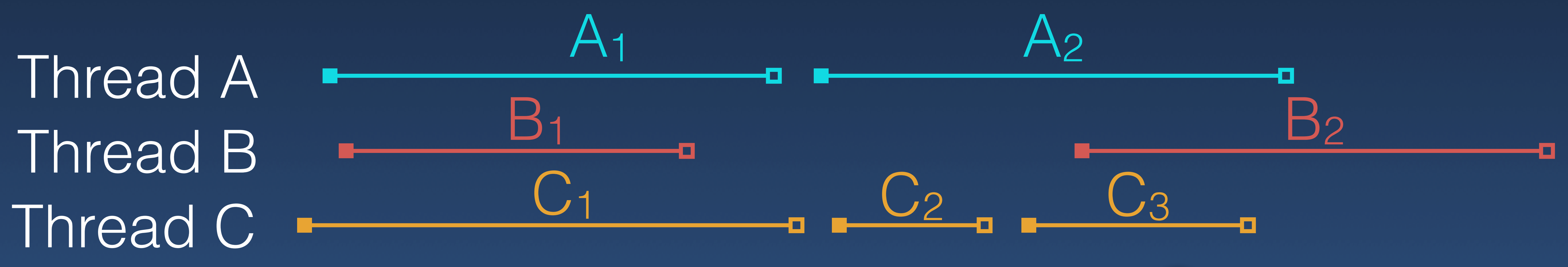

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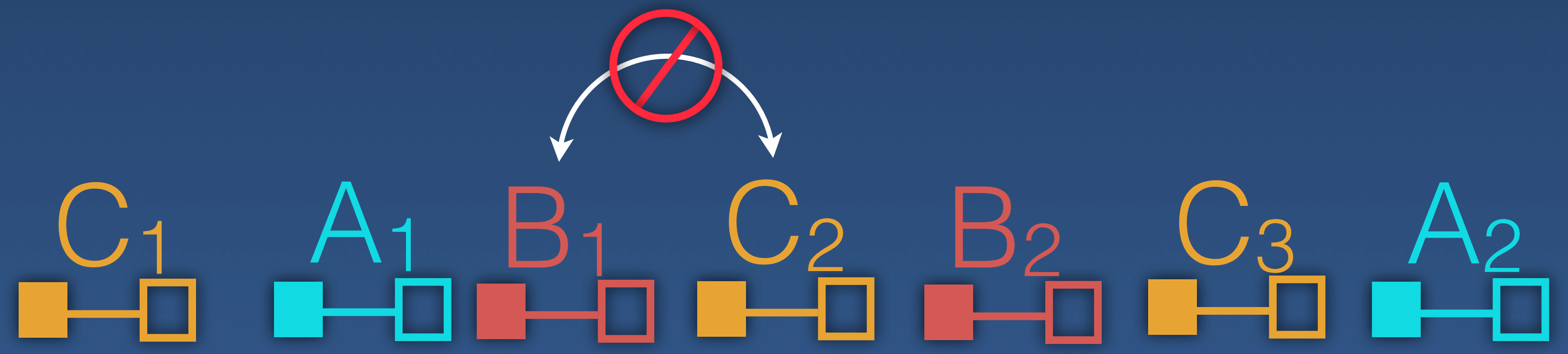

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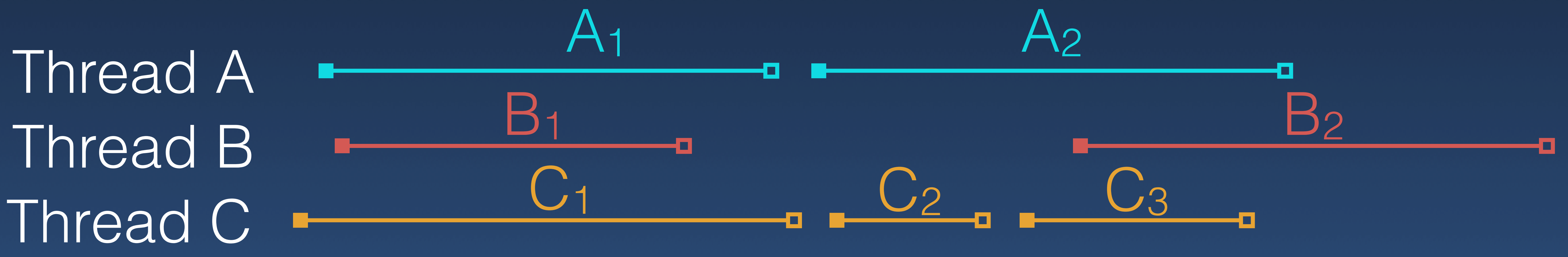

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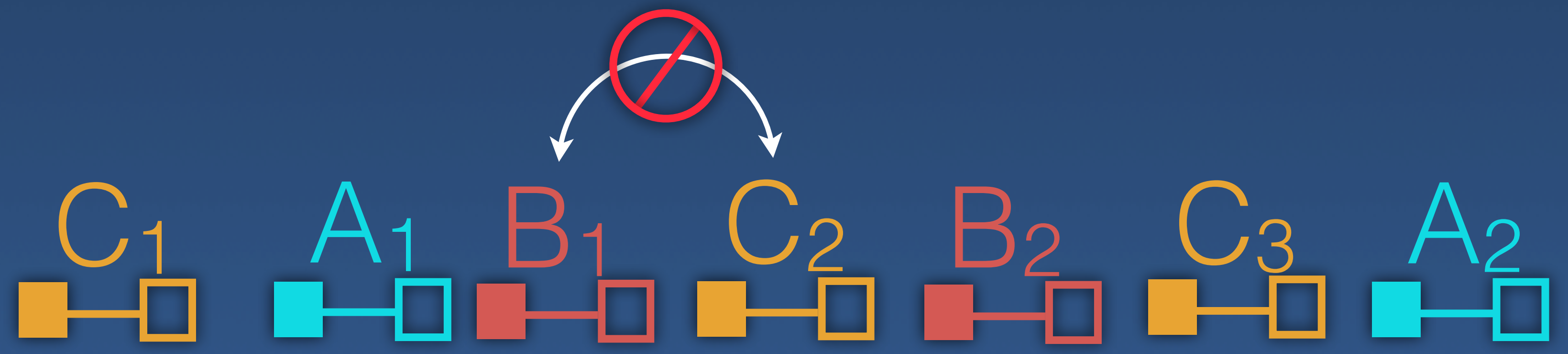

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Linearizability is Composable

Types of Registers

- Linearizable registers
  - ➡ SRSW 1-bit safe register
  - ➡ MRMW n-bit atomic linearizable register
- Sequentially consistent registers
- Causally consistent registers
- FIFO consistent registers
- Weakly consistent registers

Sequential Consistency

- "A multiprocessor is sequentially consistent if the result of any execution is the same as if the operations of all the processors were executed in some sequential order, and the operations of each individual processor appear in this sequence in the order specified by its program." [Lamport, 1979]

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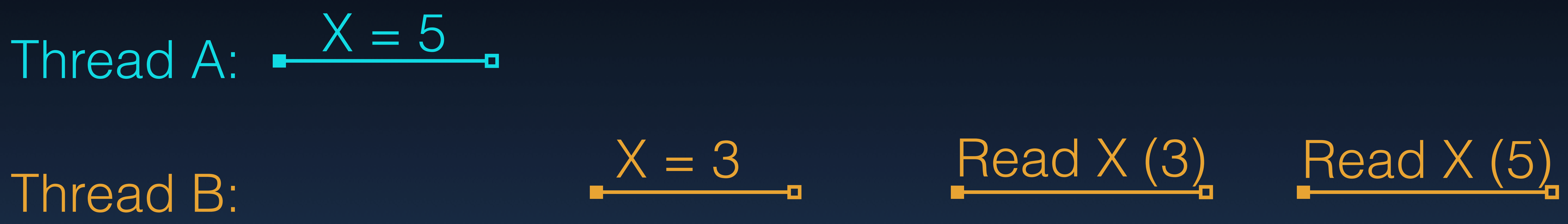
Weaker than Linearizability

Sequentially Consistent



- No global notion of time
  - ➡ Only consistent Order

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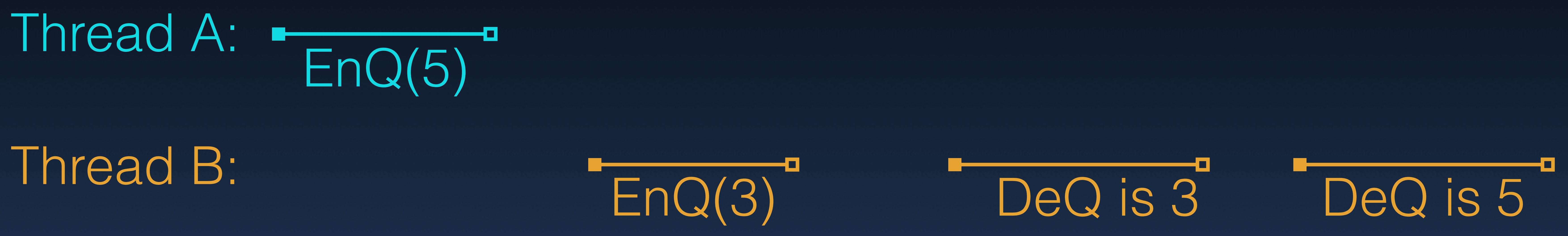

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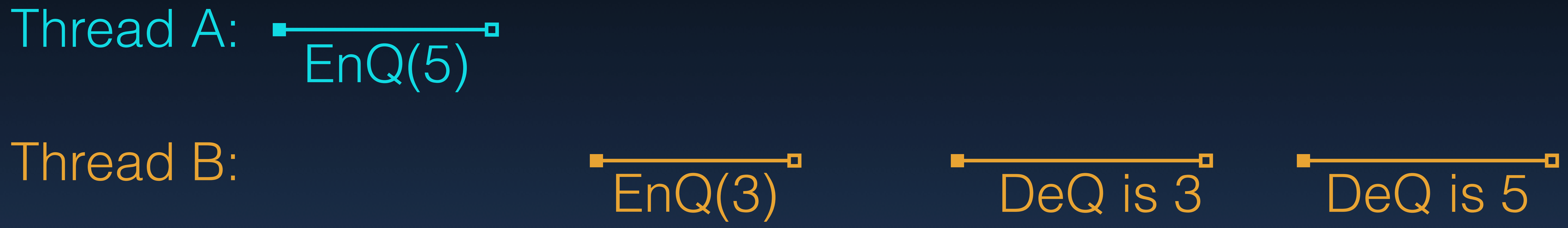

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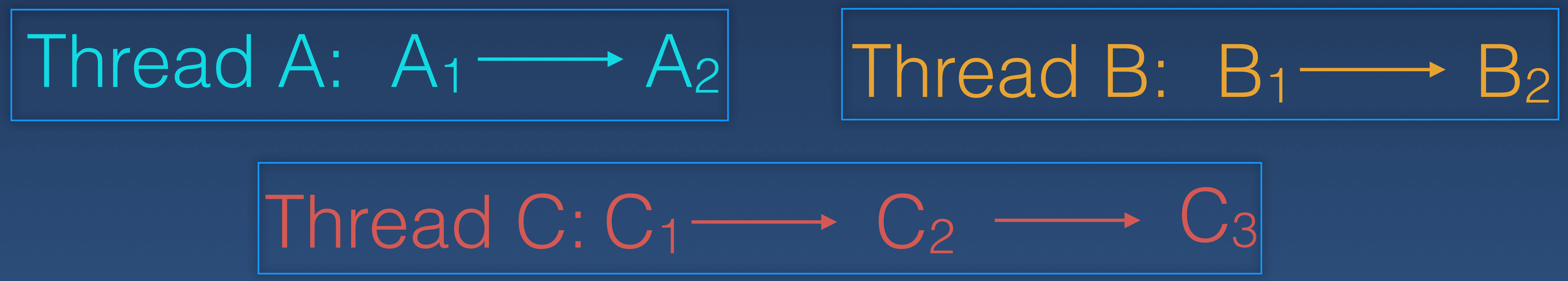

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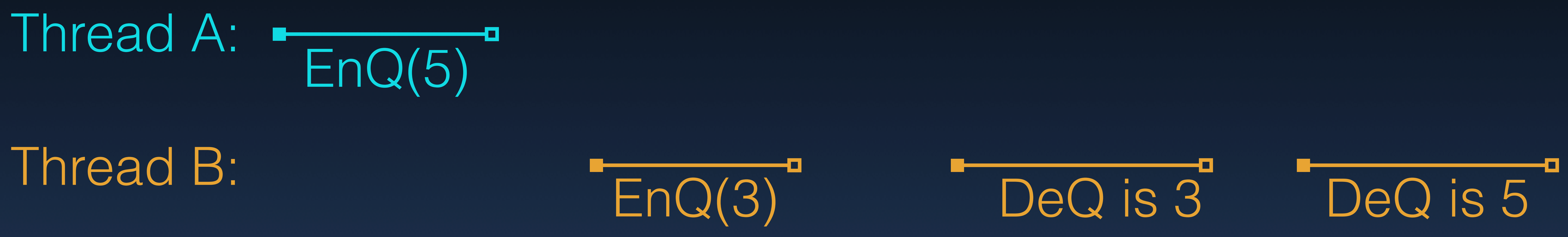

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Thread A: $A_1 \longrightarrow A_2$

Thread B: $B_1 \longrightarrow B_2$

Thread C: $C_1 \longrightarrow C_2 \longrightarrow C_3$

Sequential History

$A_1 \to A_2 \quad C_1 \to C_2 \to C_3 \quad B_1 \to B_2$

$$\begin{tikzcd}
A_1 \arrow[rr, bend left] & C_1 \arrow[rrrr, bend right] & A_2 & B_1 \arrow[r] & B_2 & C_2 \arrow[r] & C_3
\end{tikzcd}$$

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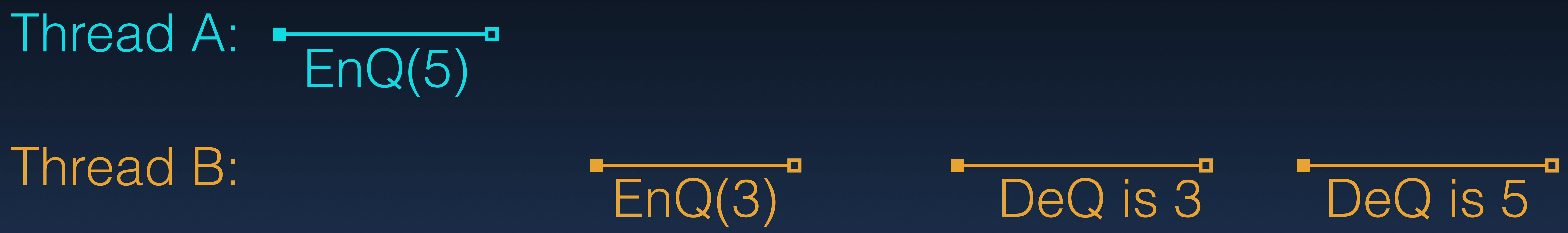

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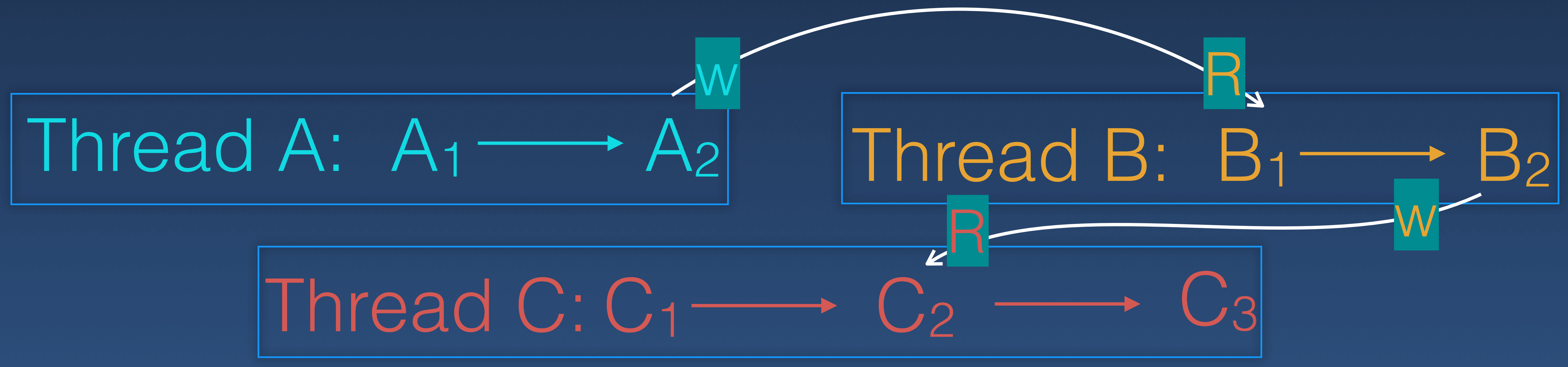

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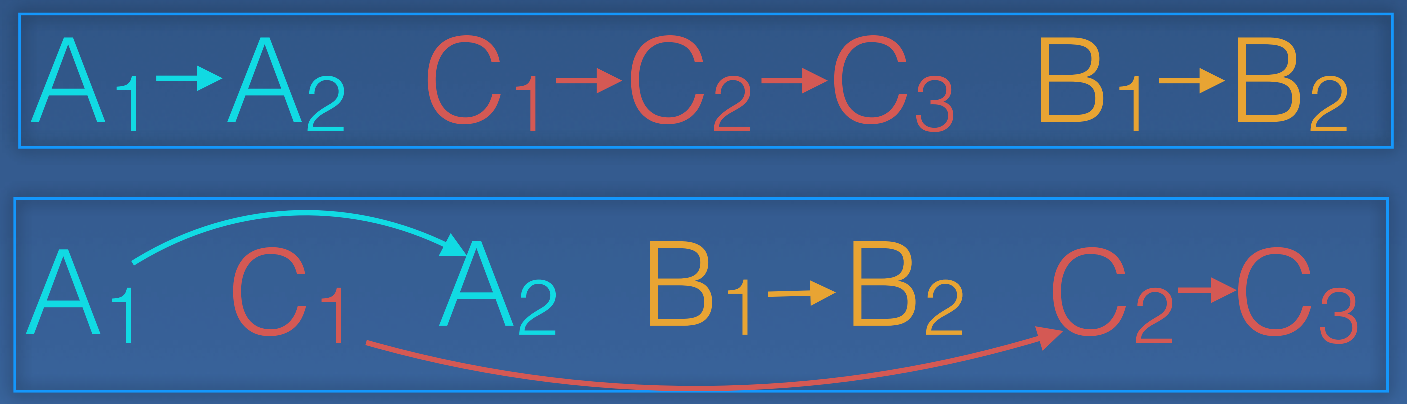

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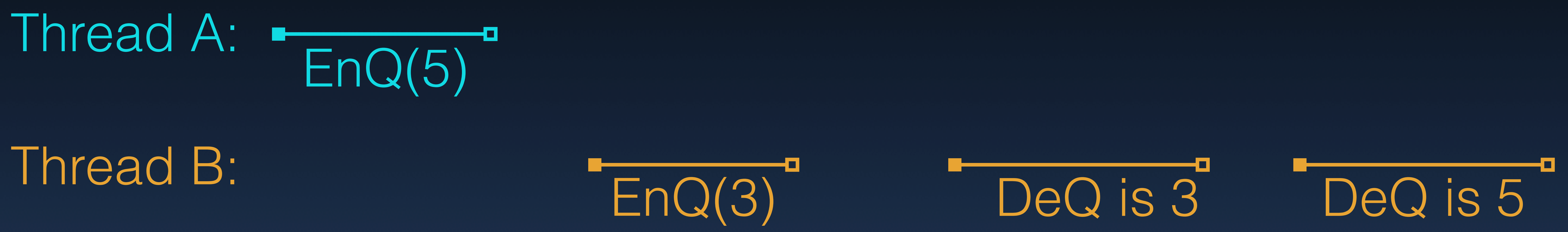

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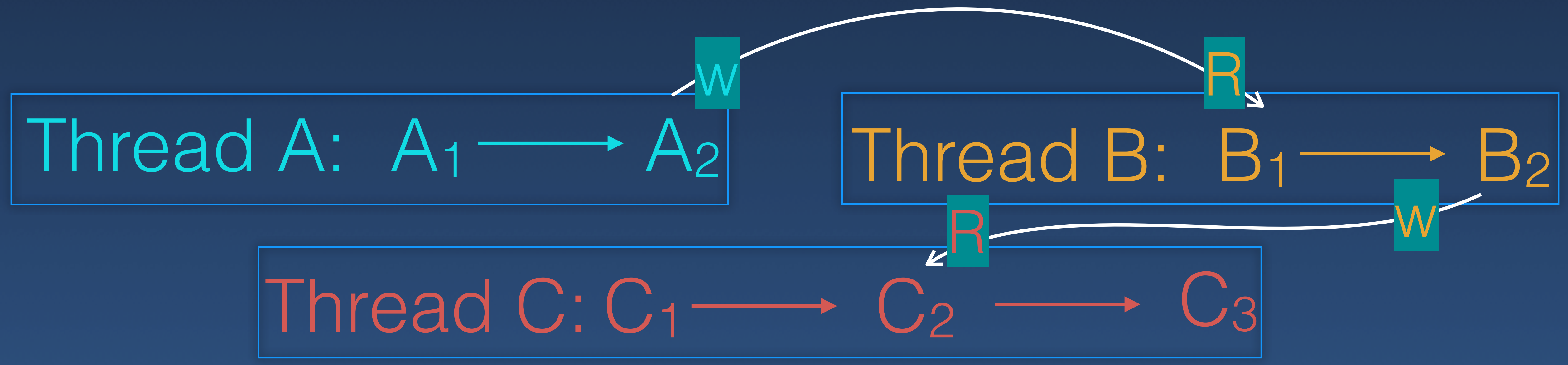

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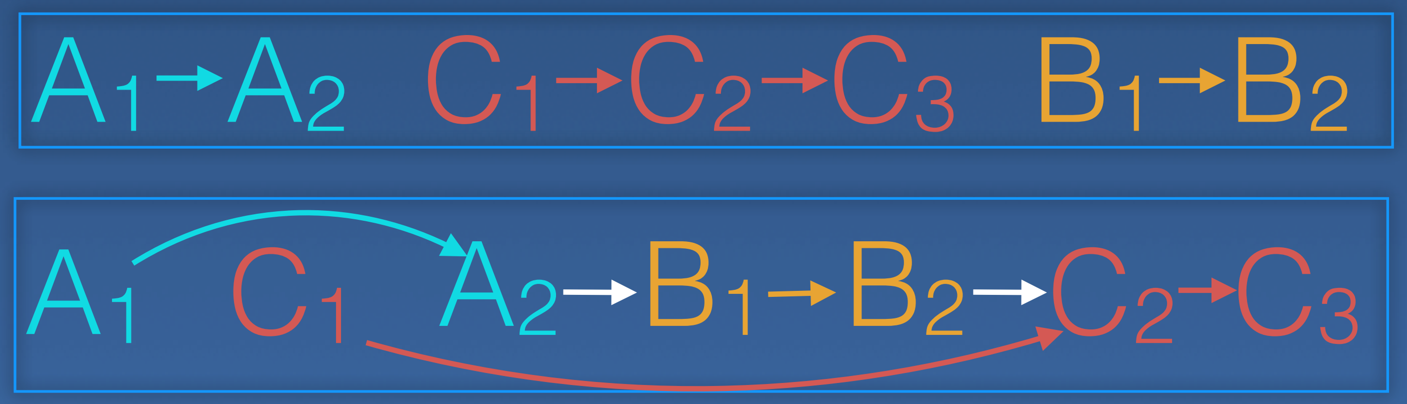

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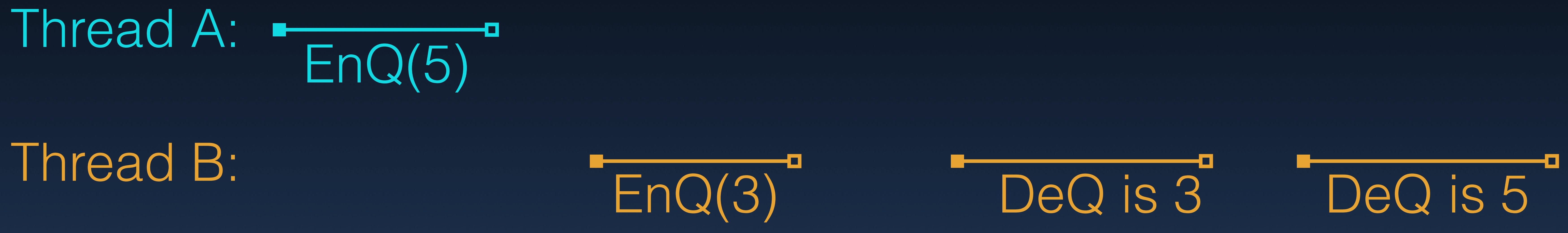

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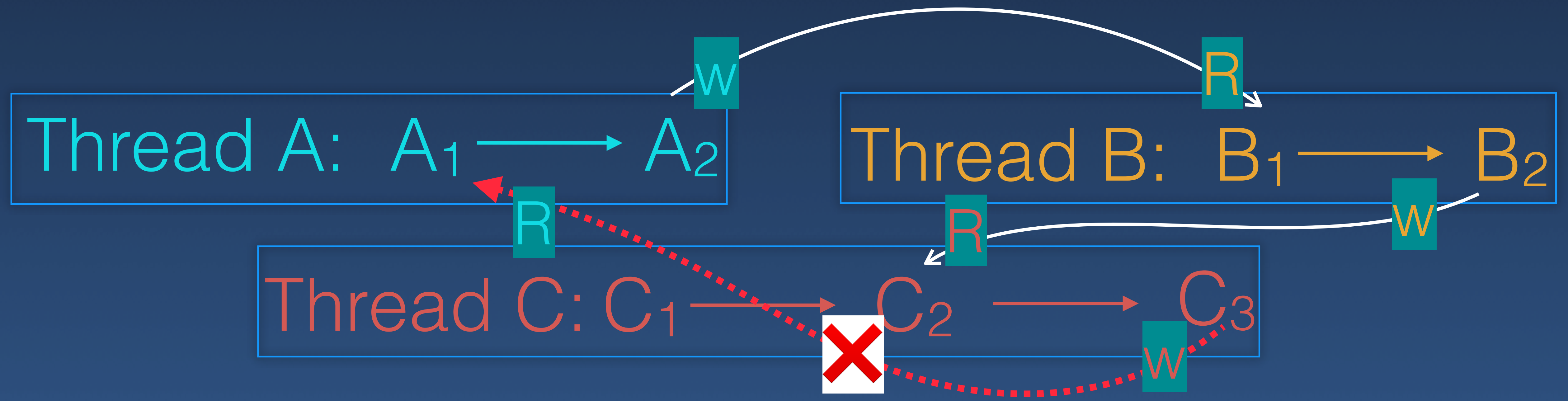

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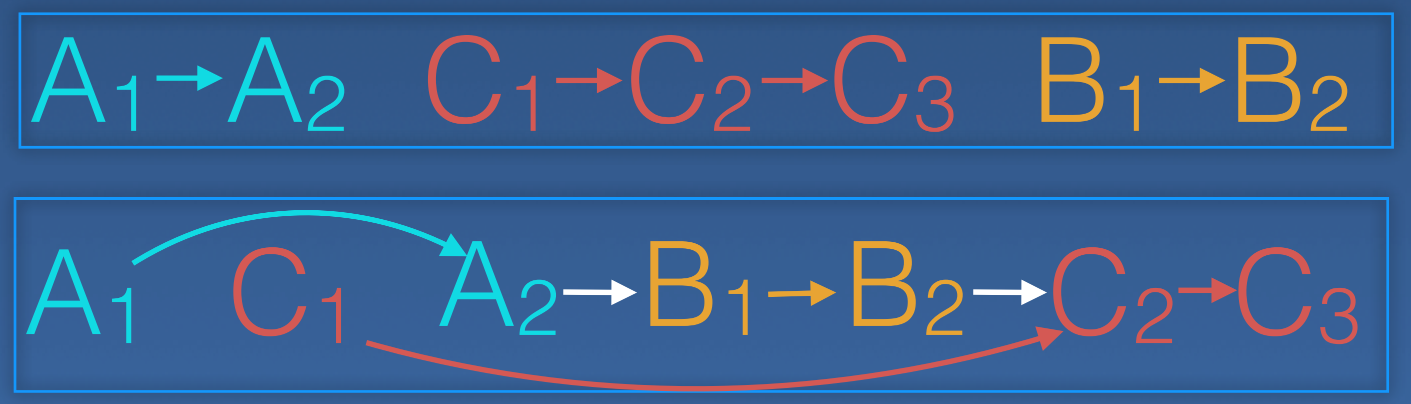

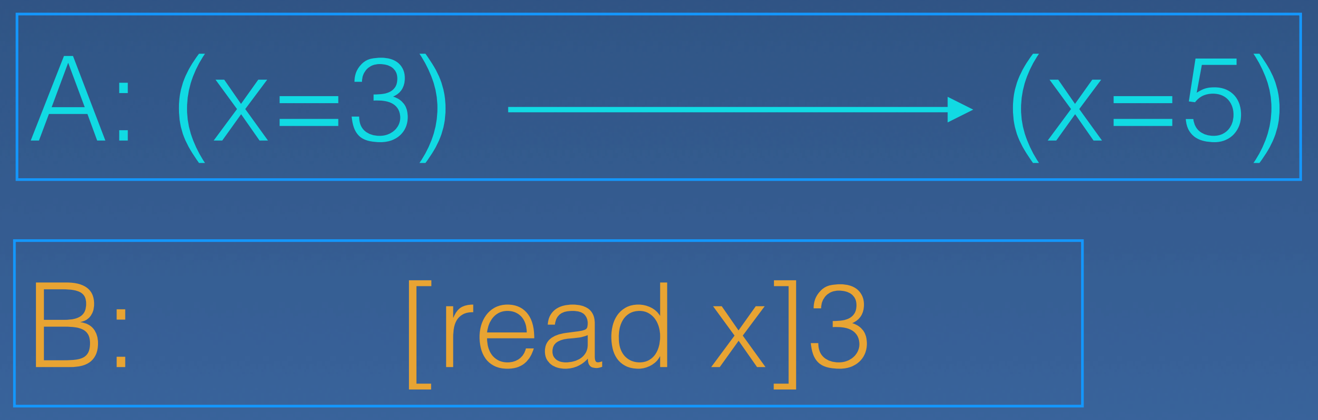

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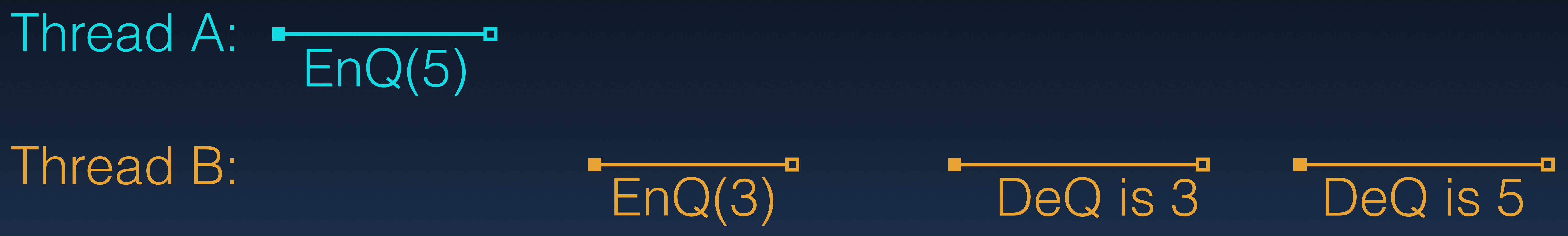

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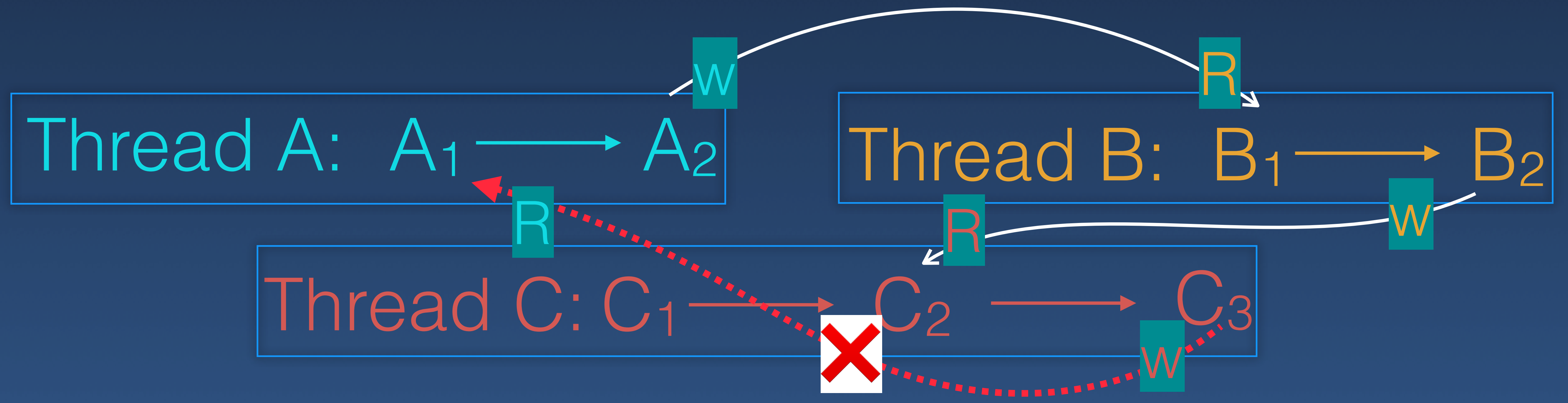

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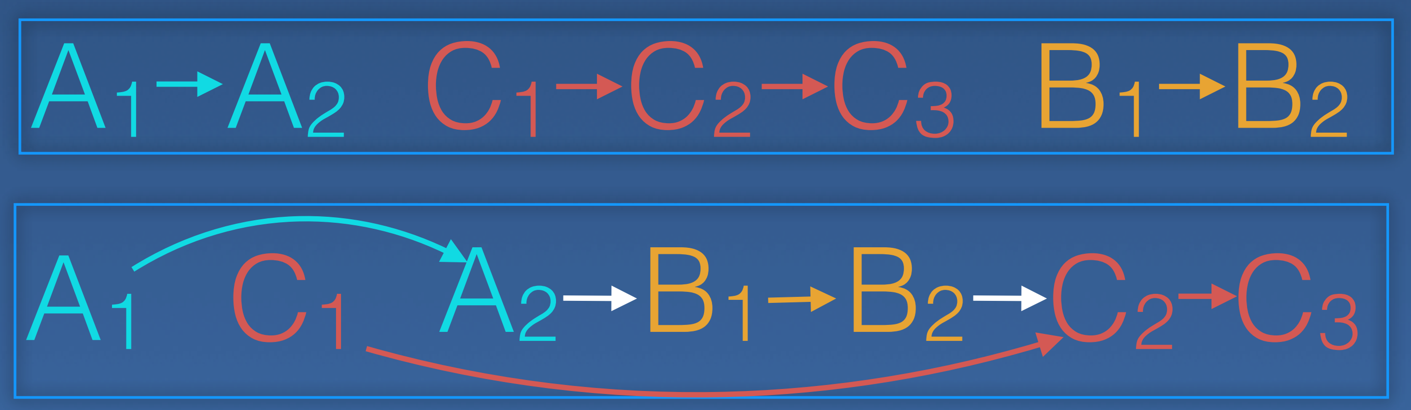

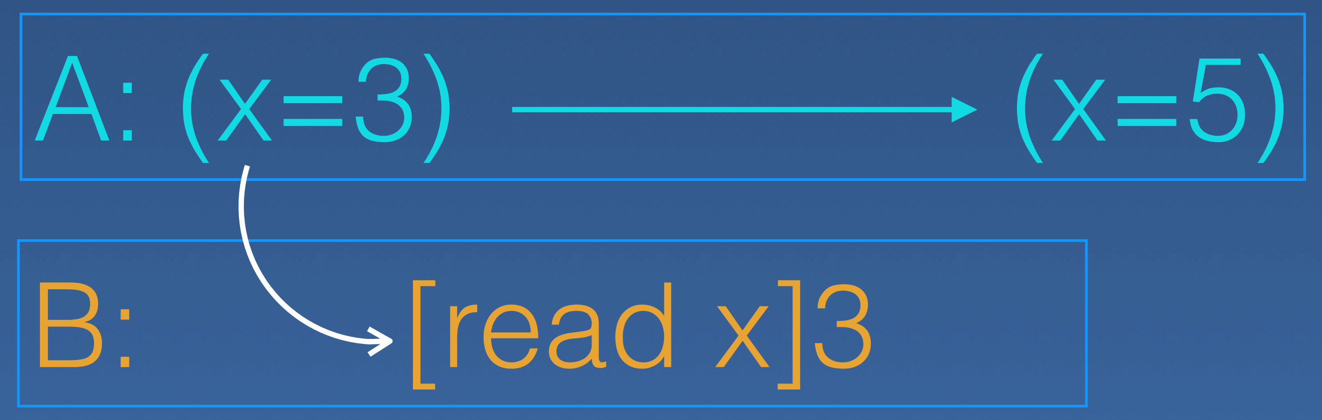

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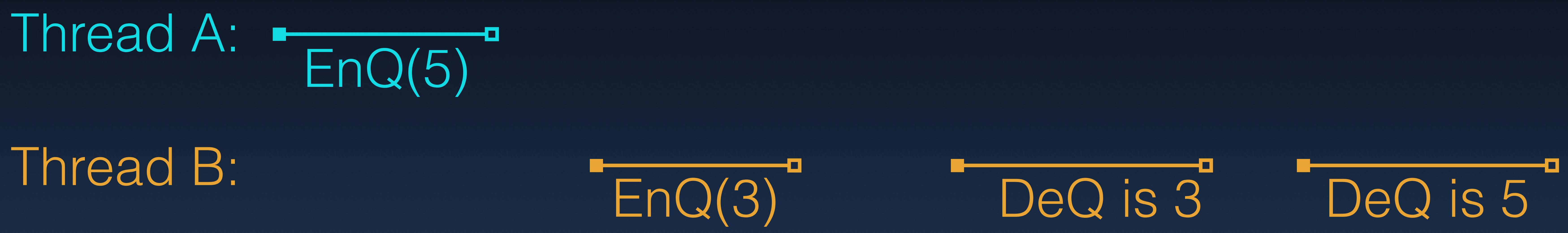

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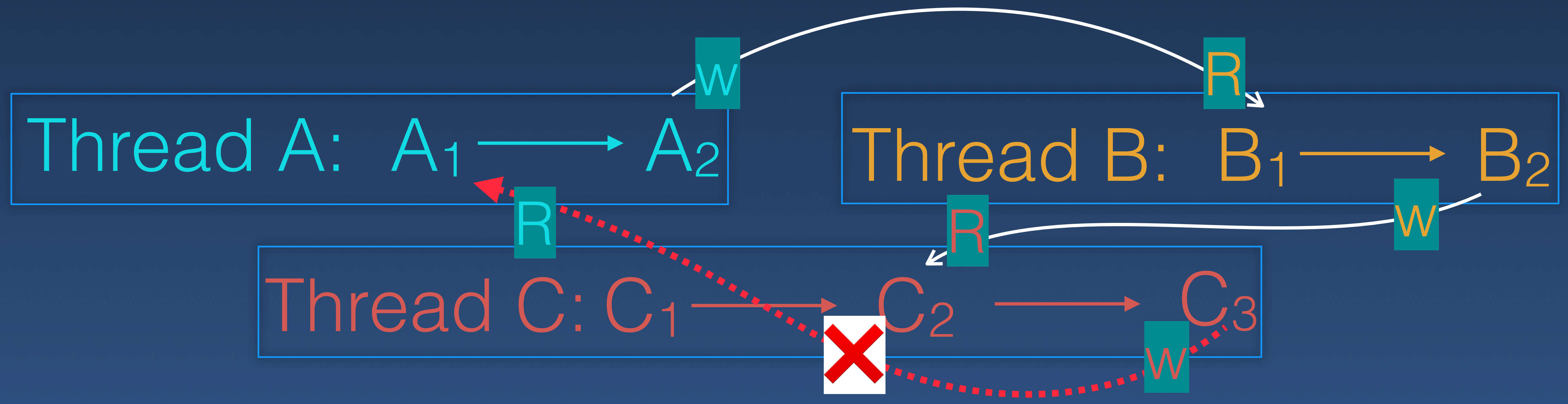

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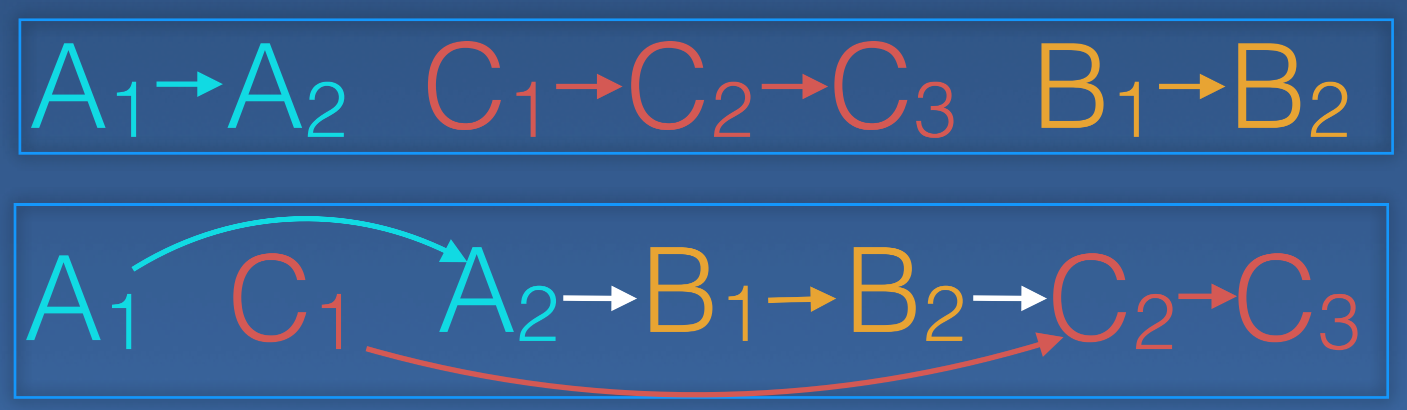

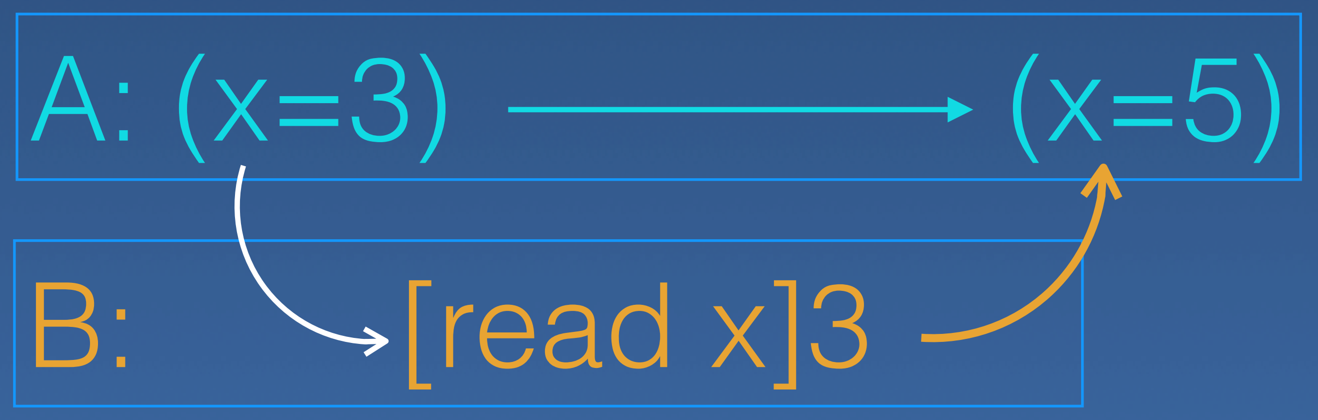

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initially:    ready=0, data=0

  thread A           thread B

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ready = 1;            pvt = data;
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Need: If B sees the new value of ready (1), B must also see the new value of data (1)

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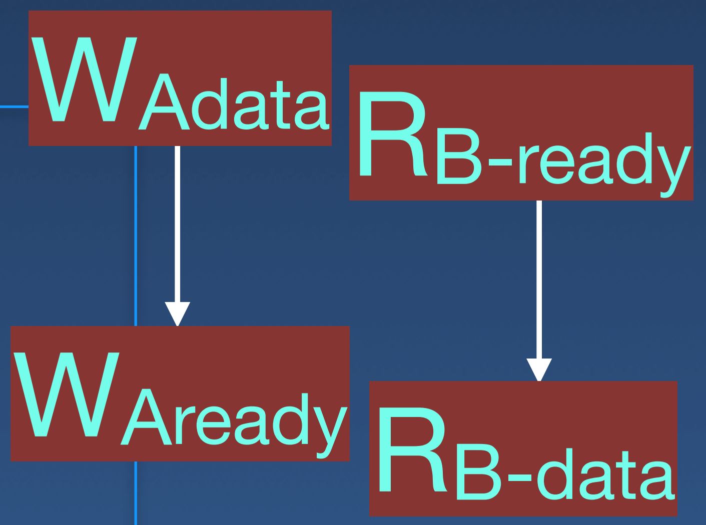
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0	0
1	1

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Review

- Linearizability
- Sequential Consistency