Note: Information on these slides is not updated during the course; please refer to the course webpage for news.

TDDD56

Lesson 1: Lab series intro

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Staff

- **August Ernstsson**, course/lab assistant, lessons
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- **Ingemar Ragnemalm**, lab assistant, GPU lectures
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- **Sehrish Qummar**, extra lab assistant
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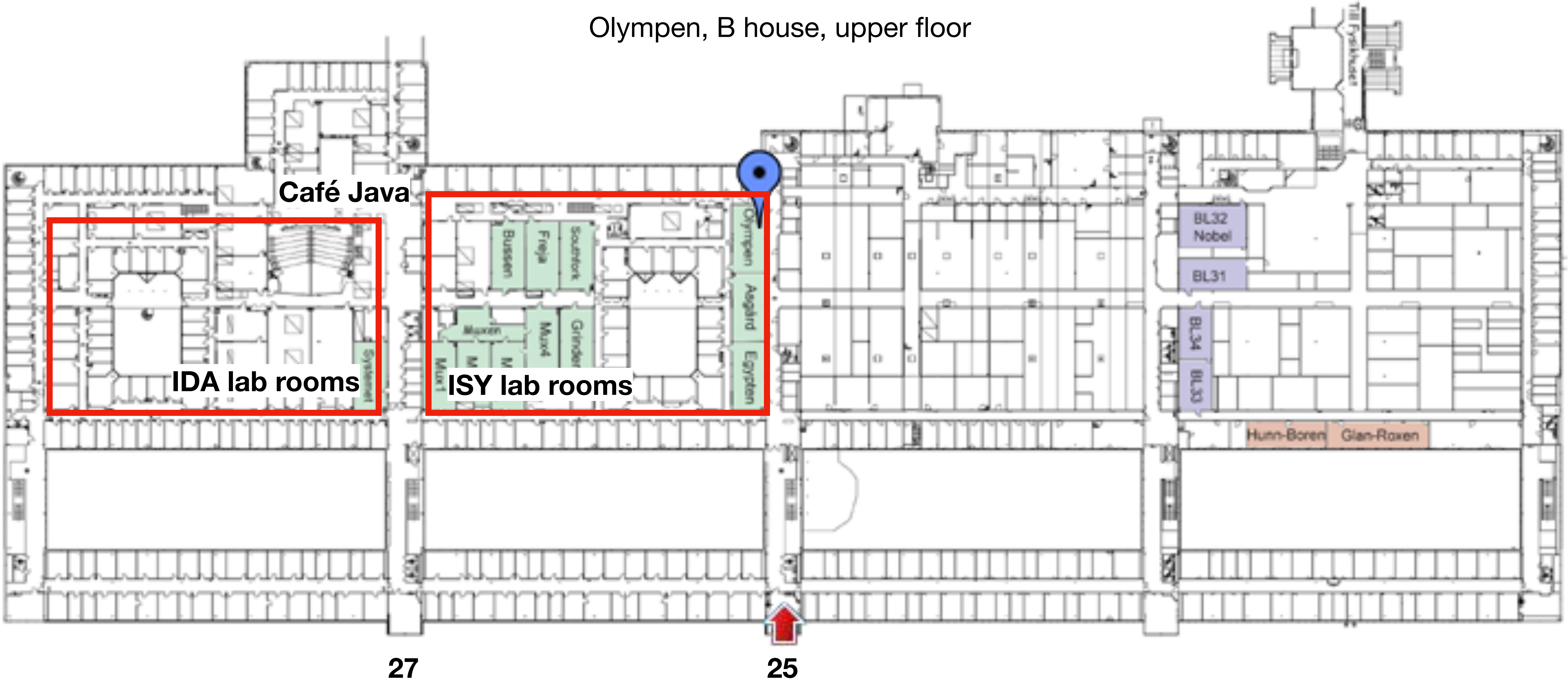
Lab groups

- Two main groups: **A** and **B**
  - Different schedule slots.
- Subgroups of two students. Work in pairs.
- Each session will be attended by one assistant.
  - For the latter half (GPU part), Ingemar takes over supervision of group A.

Lab room

Olympen, B house, upper floor



Lab equipment

- Olympen has special lab computers for the course
  - May be able to use other IDA systems or own equipment for development, but use **Olympen machines** for performance testing and demonstration.
- 16 seats for groups of 2 students = 32 students at once in room
  - Intel Xeon CPU W-2145
  - 8 cores, 3.70 GHz
  - 16 GiB memory

Lab schedule

Responsible		WebReg	Week	Topic	Lesson
Responsible: August	CPU	Lab 1	v45	Load Balancing	Lesson 1
		Lab 2	v46	Non-blocking Data Structures	Lesson 1
		Lab 3	v47	High-level Parallel Programming	Lesson 2
Responsible: Ingemar	GPU	Lab 4	v48	CUDA 1	
		Lab 5	v49	CUDA 2	
		Lab 6	v50	OpenCL	

General info

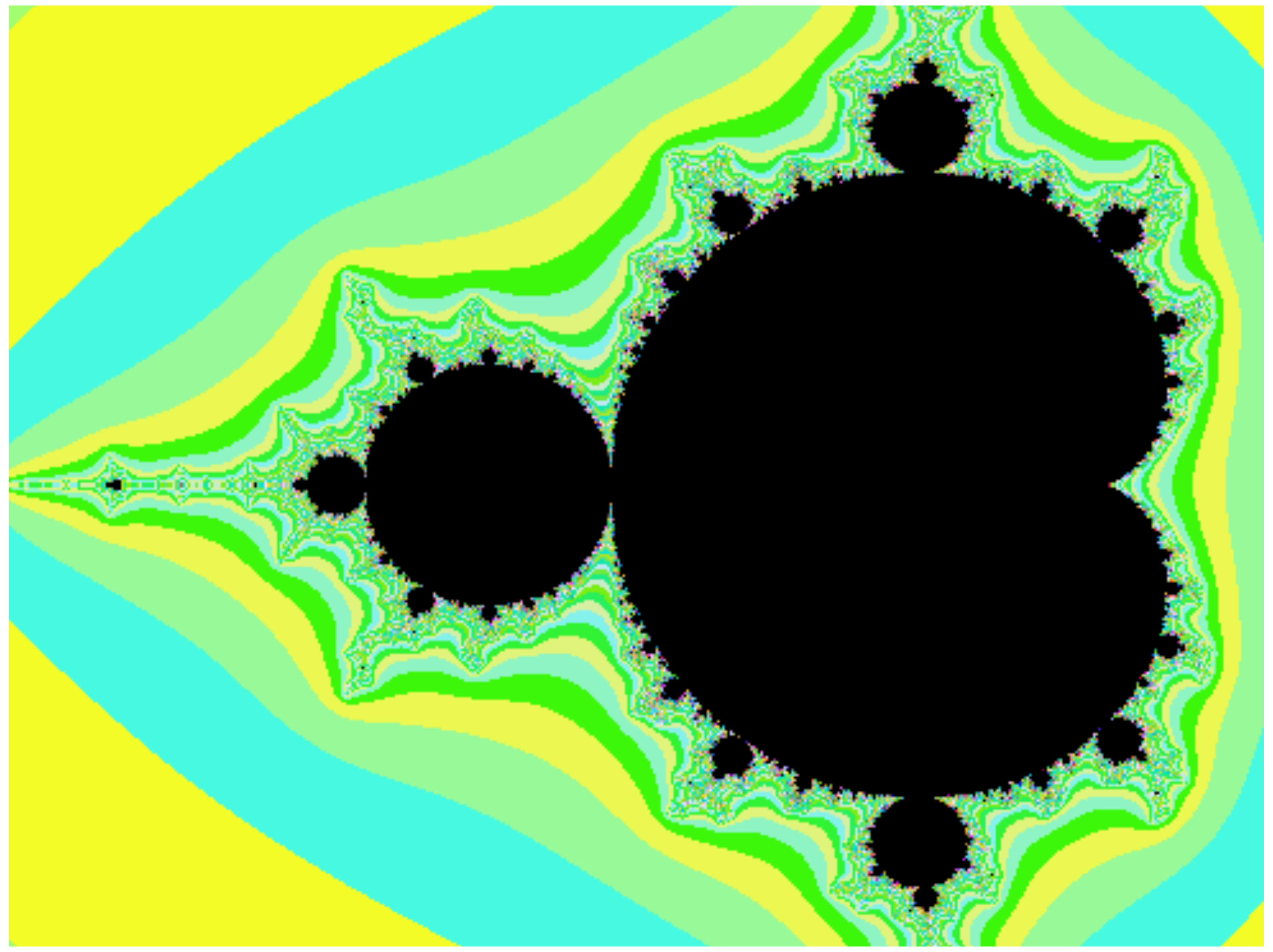
- **Be prepared** when coming to labs, use time with teachers well!
- Lab compendiums and resources (code skeletons etc.) on course webpage.
- **Ask** if something is unclear.
- **Demonstrate** your solutions and provide answers to any questions asked in lab material, as well as questions asked by assistant.
- No written lab reports, so demonstration is thorough!
- **Both** members of a group should be actively contributing and be prepared to answer questions during demonstration.
- It is allowed to discuss among groups, but don't share solutions.
  Plagiarism is taken seriously!

Information Resources

- Lab instructions
- Source files
- TDDD56 lecture, lesson slides

Lab 1 – Load Balancing

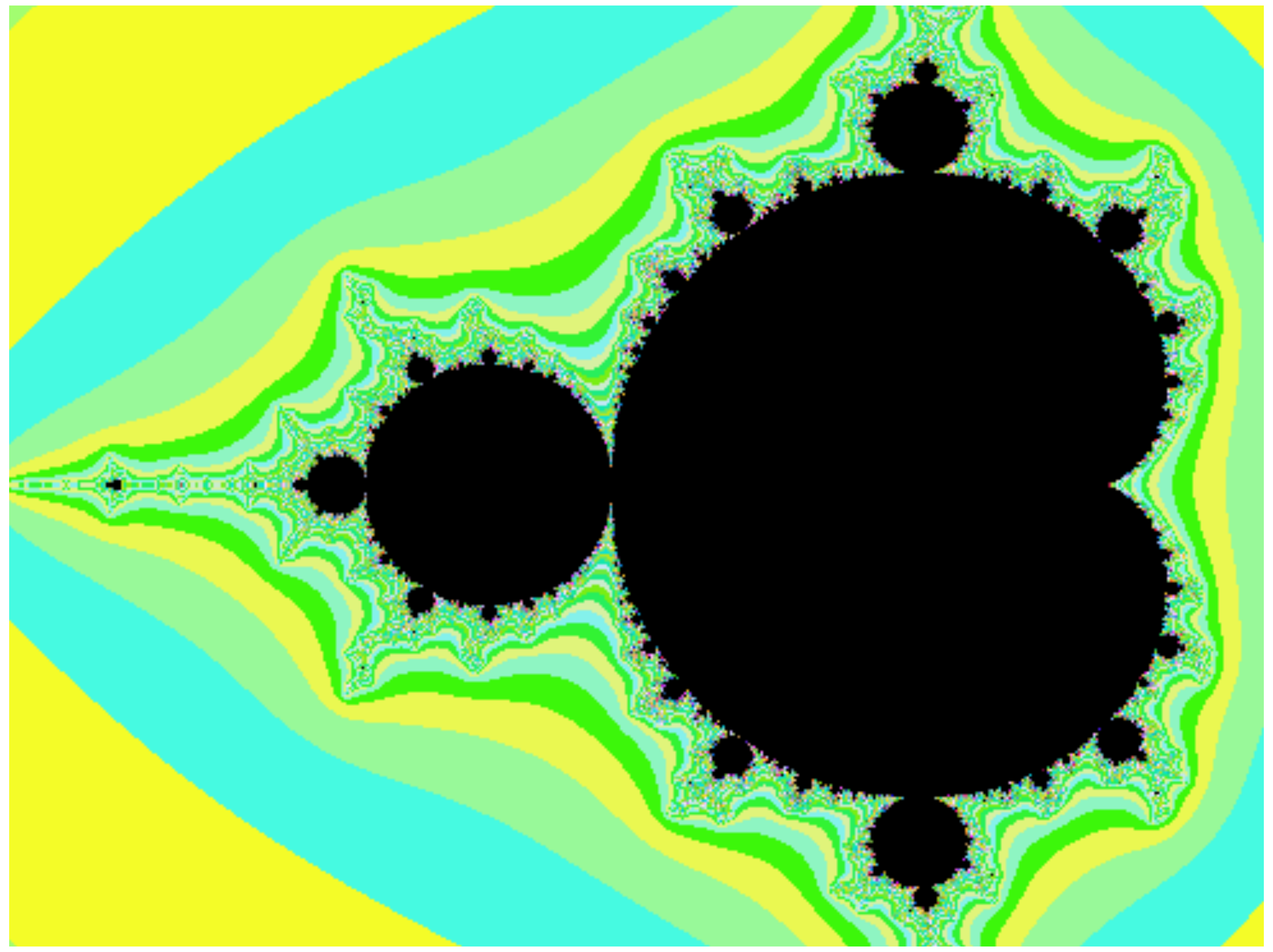
- Working with threads (Pthreads) on multicore CPU
- Mandelbrot fractal image generation
  - Test if a complex number is in the Mandelbrot set
  - For those interested in the maths, check out:
    - https://en.wikipedia.org/wiki/Mandelbrot_set
    - https://www.youtube.com/watch?v=NGMRB4O922I



$$f_c(z) = z^2 + c$$

Mandelbrot Algorithm

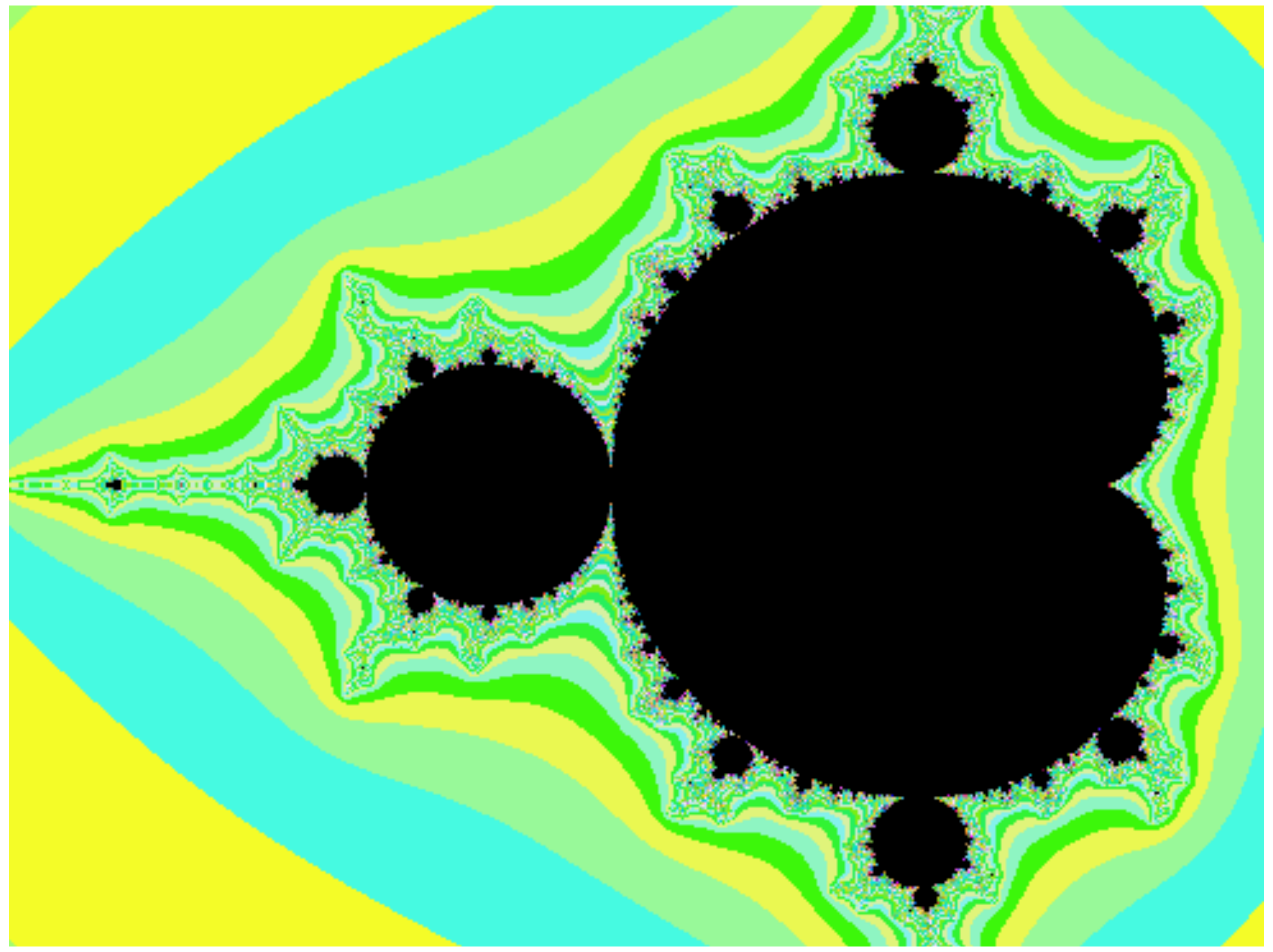
```
int is_in_Mandelbrot(float Cre, float Cim)
{
   int iter;
   float x=0.0, y=0.0, xto2=0.0, yto2=0.0, dist2;

   for (iter = 0; iter <= MAXITER; iter++)
   {
      y = x * y;
      y = y + y + Cim;
      x = xto2 - yto2 + Cre;
      xto2 = x * x;
      yto2 = y * y;
      dist2 = xto2 + yto2;
      if ((int)dist2 >= MAXDIST)
         break; // diverges
  }
   return iter;
}
```



$$f_c(z) = z^2 + c$$

Load Balancing

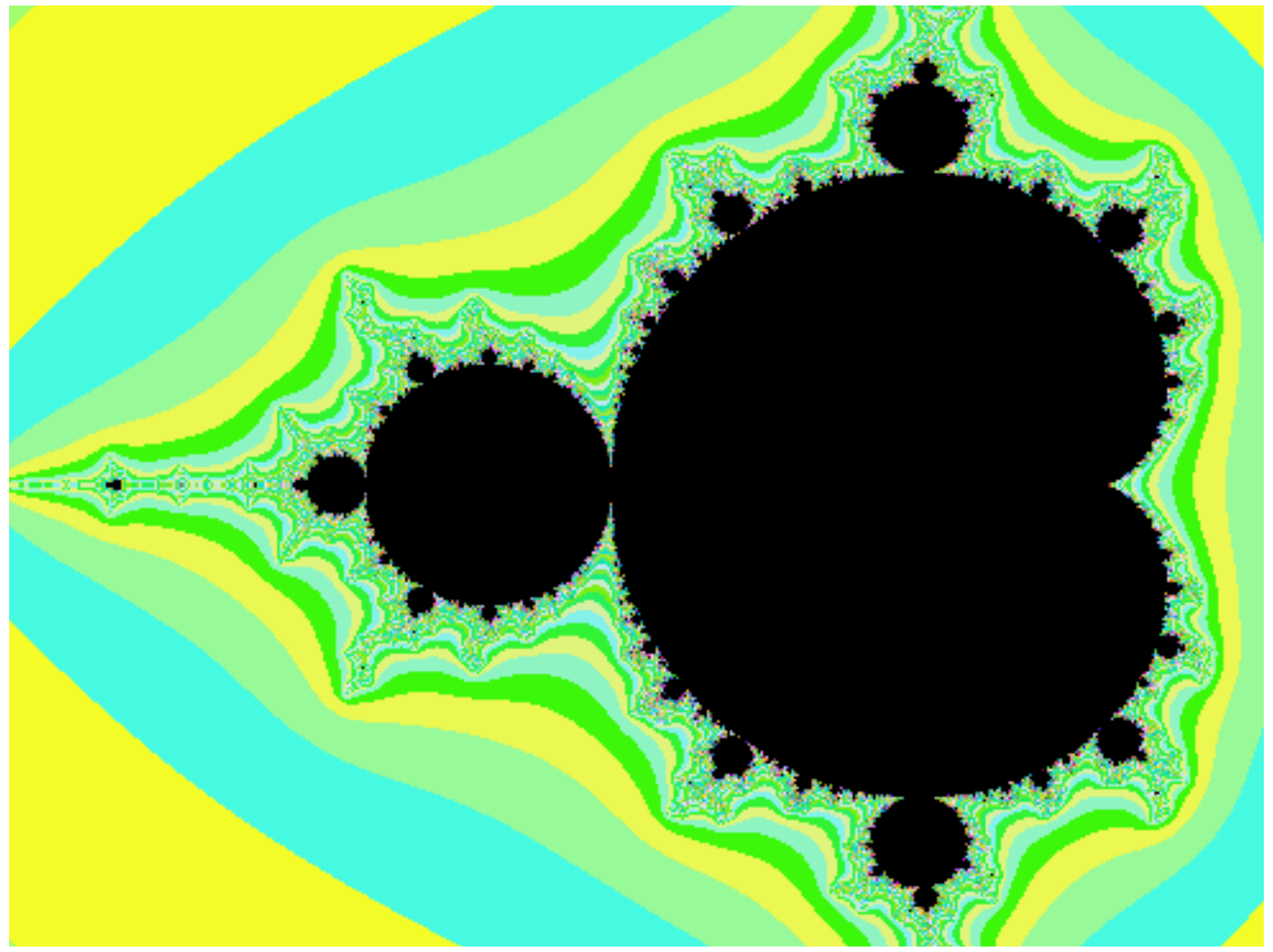
- Each image pixel is an **independent unit** of work
  - => ”Embarrassingly” parallel!
- However, all pixels are not **equal amount** of work
  - Load balancing becomes a problem!



$$f_c(z) = z^2 + c$$

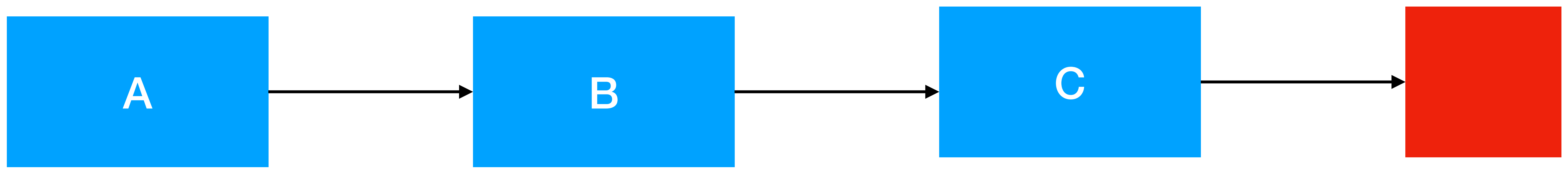
Lab 1

- Goals for the lab:
  - Implement a solution with **near-equal load**
  - Try different approaches
  - Utilize properties of the domain
    - How well will your solution work in a general case?



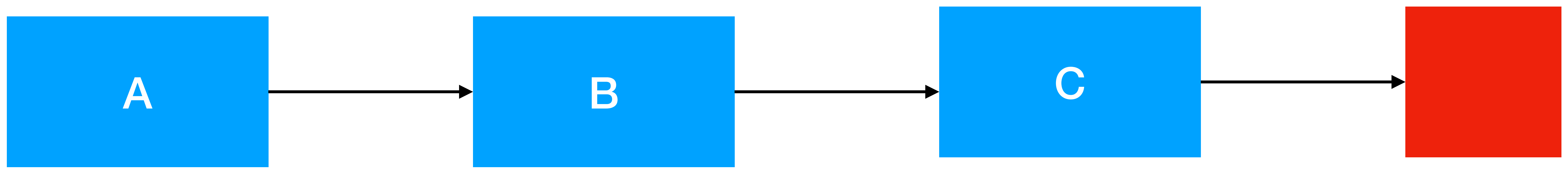
$$f_c(z) = z^2 + c$$

Lab 2: Non-blocking Stack



- Working with Pthreads on multicore CPU
- Using atomic operations (CAS)
- Implementing efficient parallel data structures

Unbounded Stacks



- Stacks implemented as **linked lists**
- Non-blocking: **NO LOCKS**!
- **Push** and **Pop** operations with atomic instructions

Compare-and-Swap

- Do atomically:
  - If *pointer* != *old pointer*: do nothing
    Else: swap *pointer* to *new pointer*
- Typically used only for compare + assign, no swap

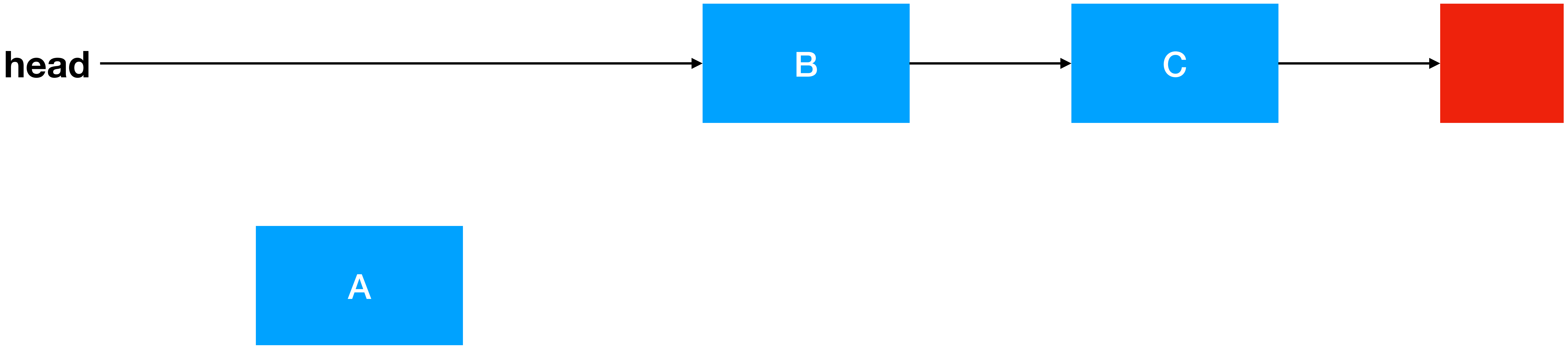
```
CAS(void** pointer, void* old, void* new)
  {
     atomic {
        if(*pointer == old)
           *pointer = new;
     }
     return old;
  }
```

CAS for Stack

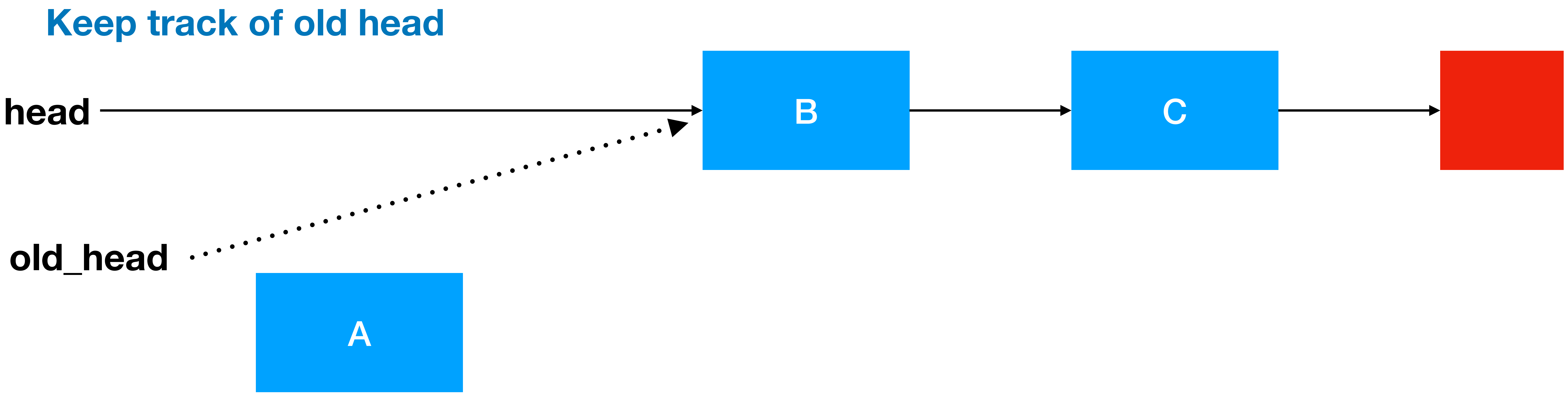
```
do {
    old = head; elem.next = old;
} while(CAS(head, old, elem) != old);
```

- Push
  - Keep track of old head
  - Set new elements next pointer to old head
  - **Atomically**:
    - Compare current head with saved old head
    - If still equal, set list head to new element

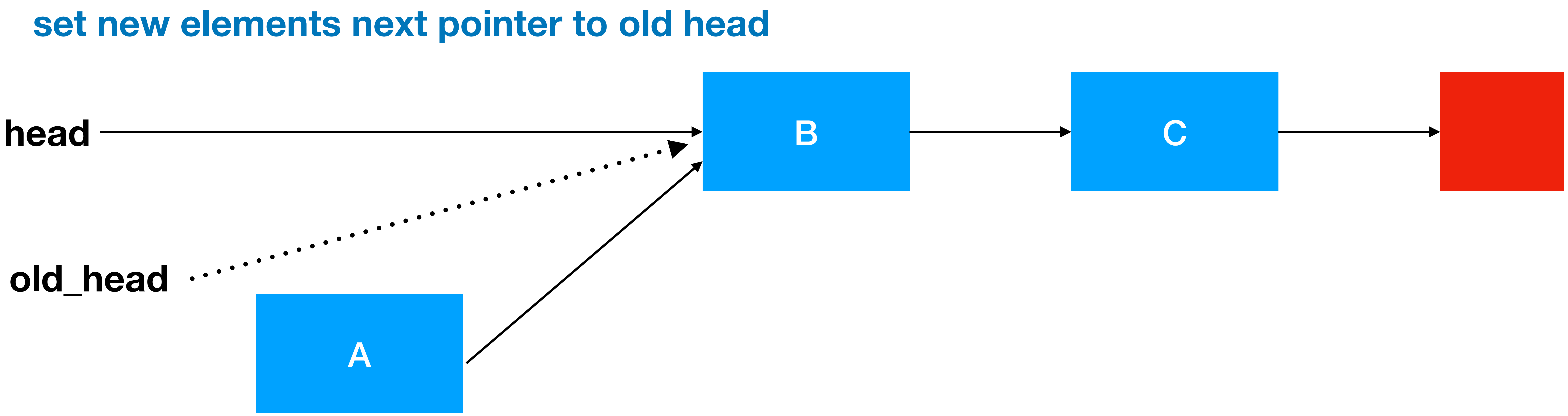
CAS push



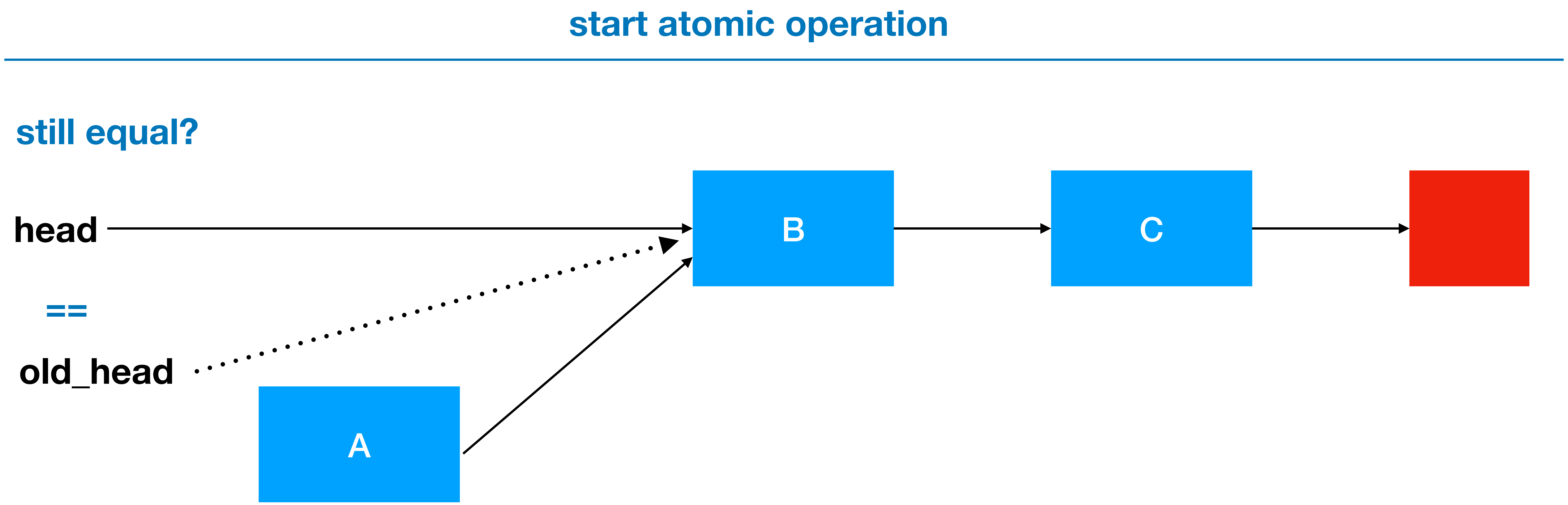
CAS push



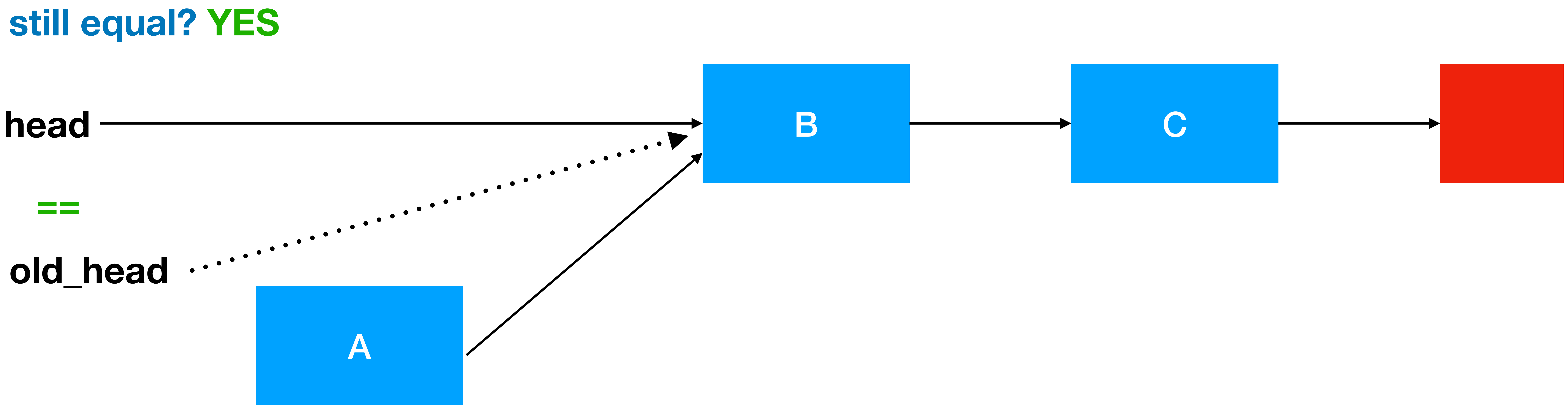
CAS push



CAS push, success

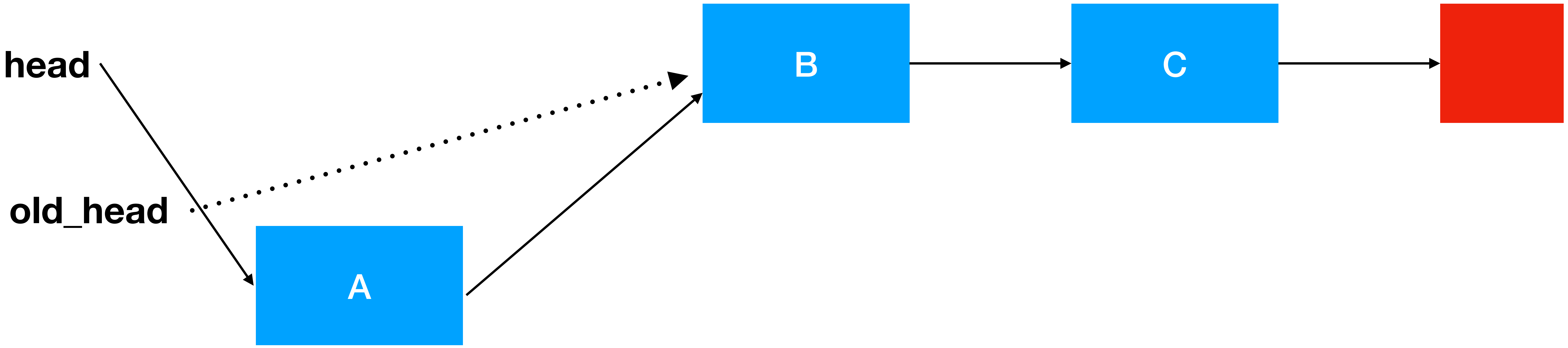


CAS push, success



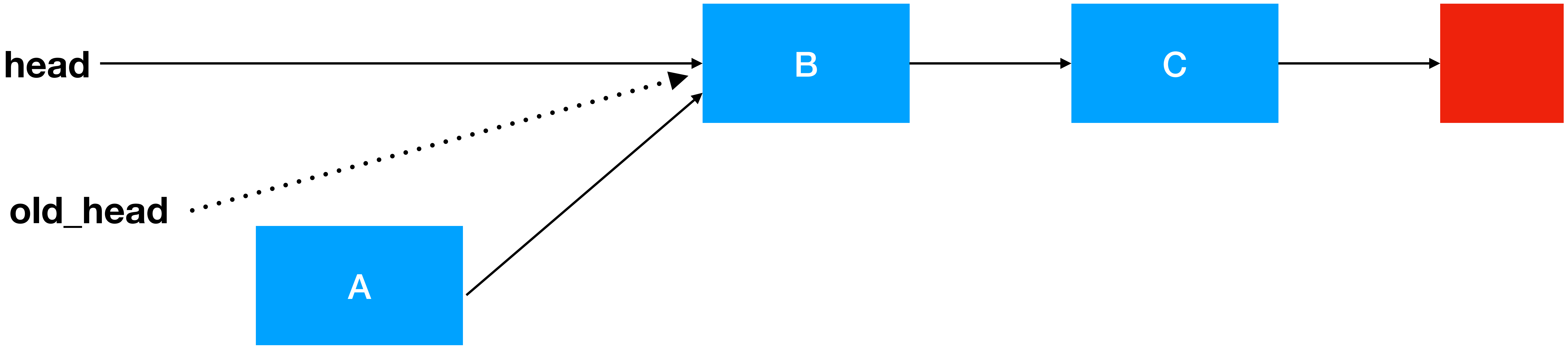
CAS push, success

set list head to new element

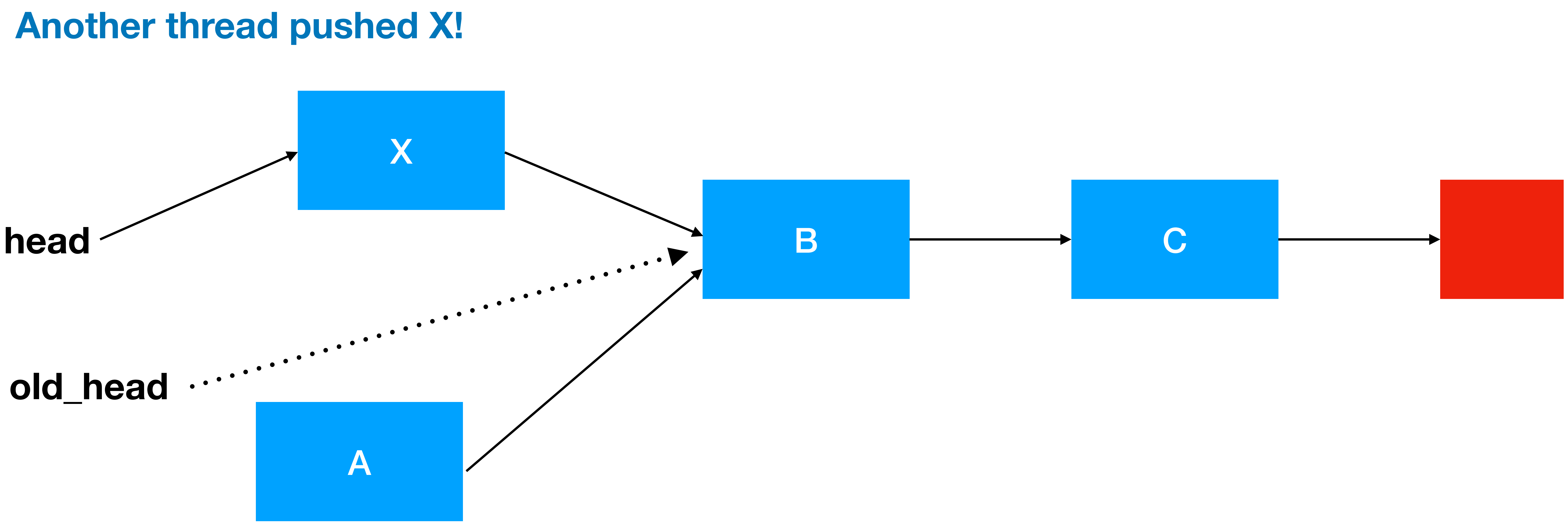


end atomic operation

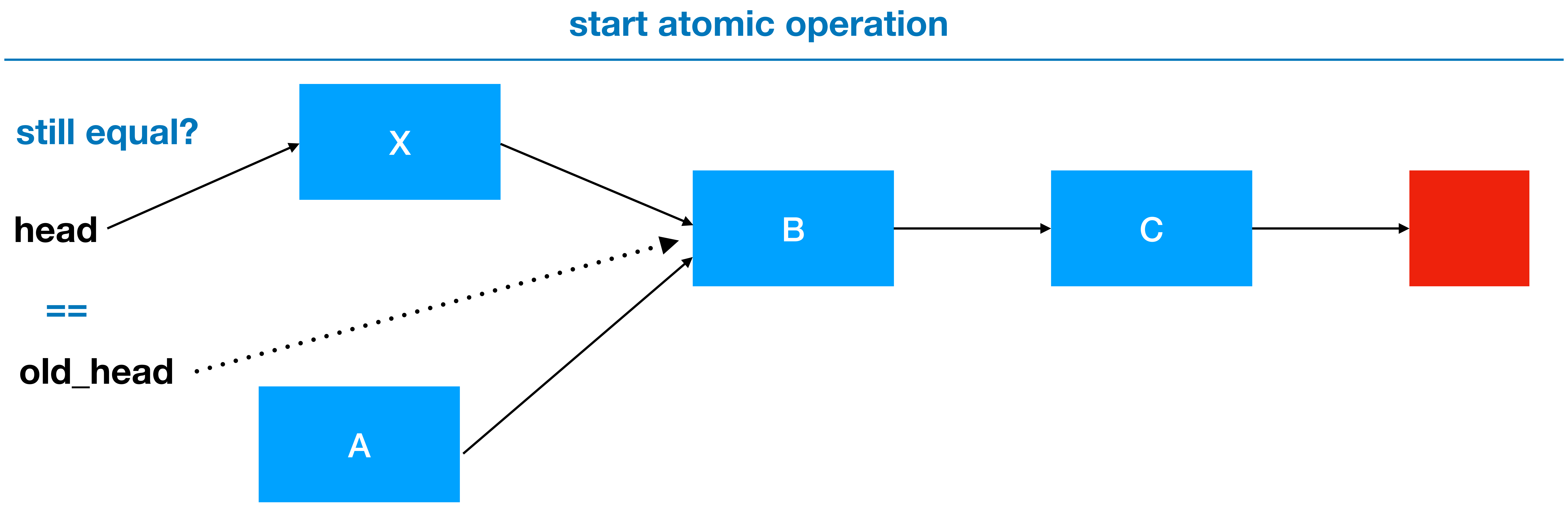
CAS push



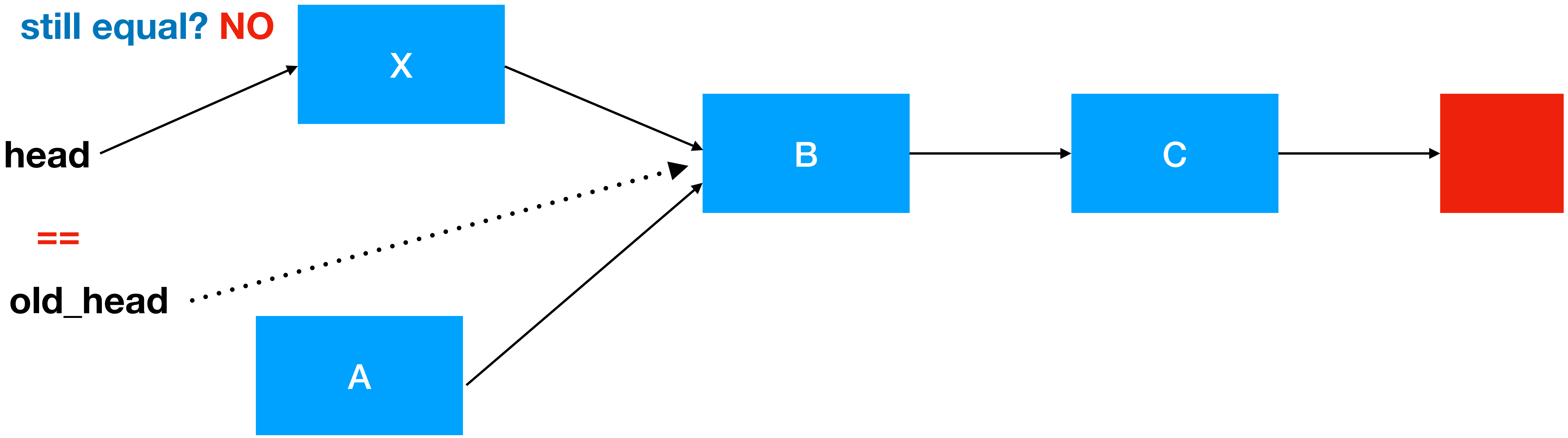
CAS push



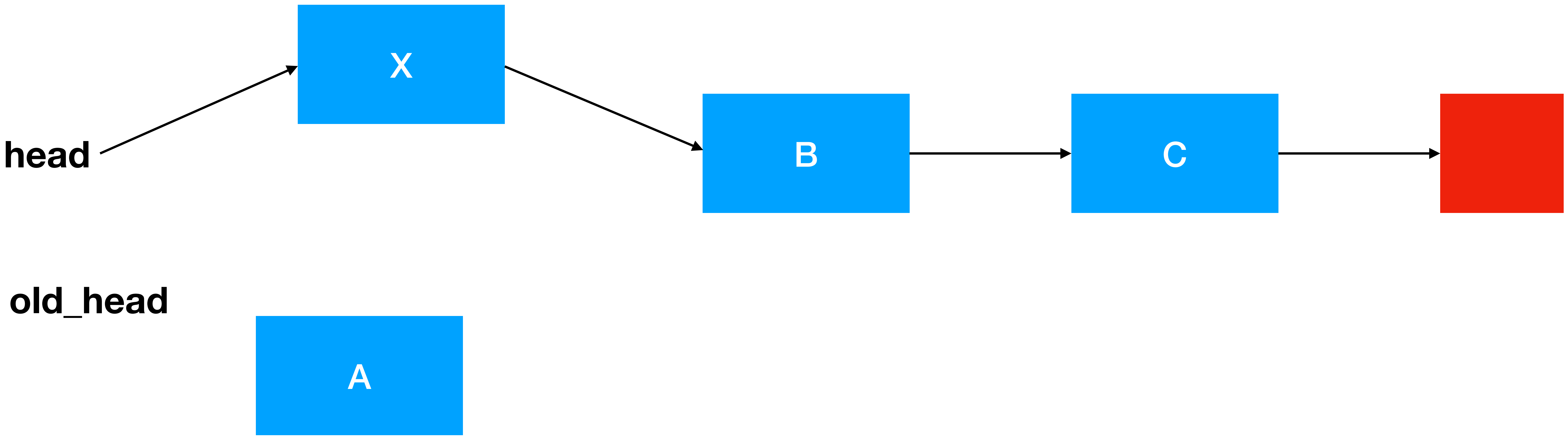
CAS push, failure



CAS push, failure



CAS push, failure



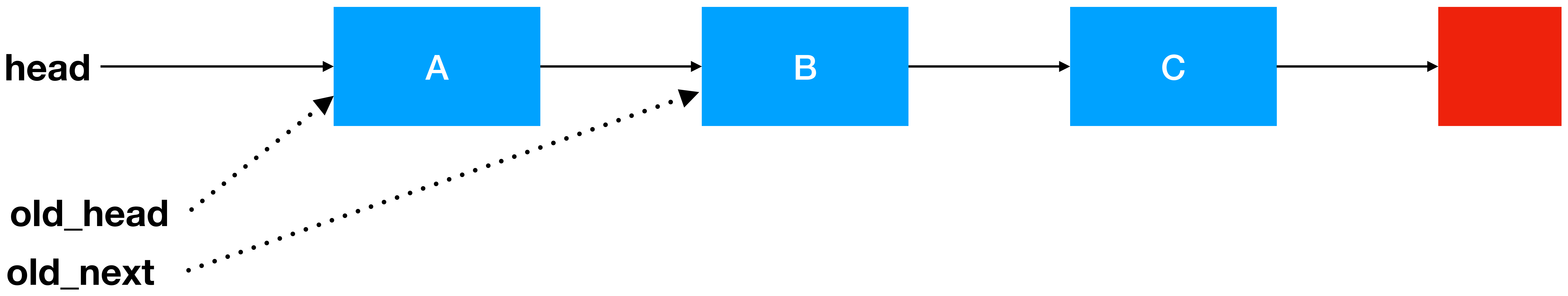
end atomic operation

ABA problem

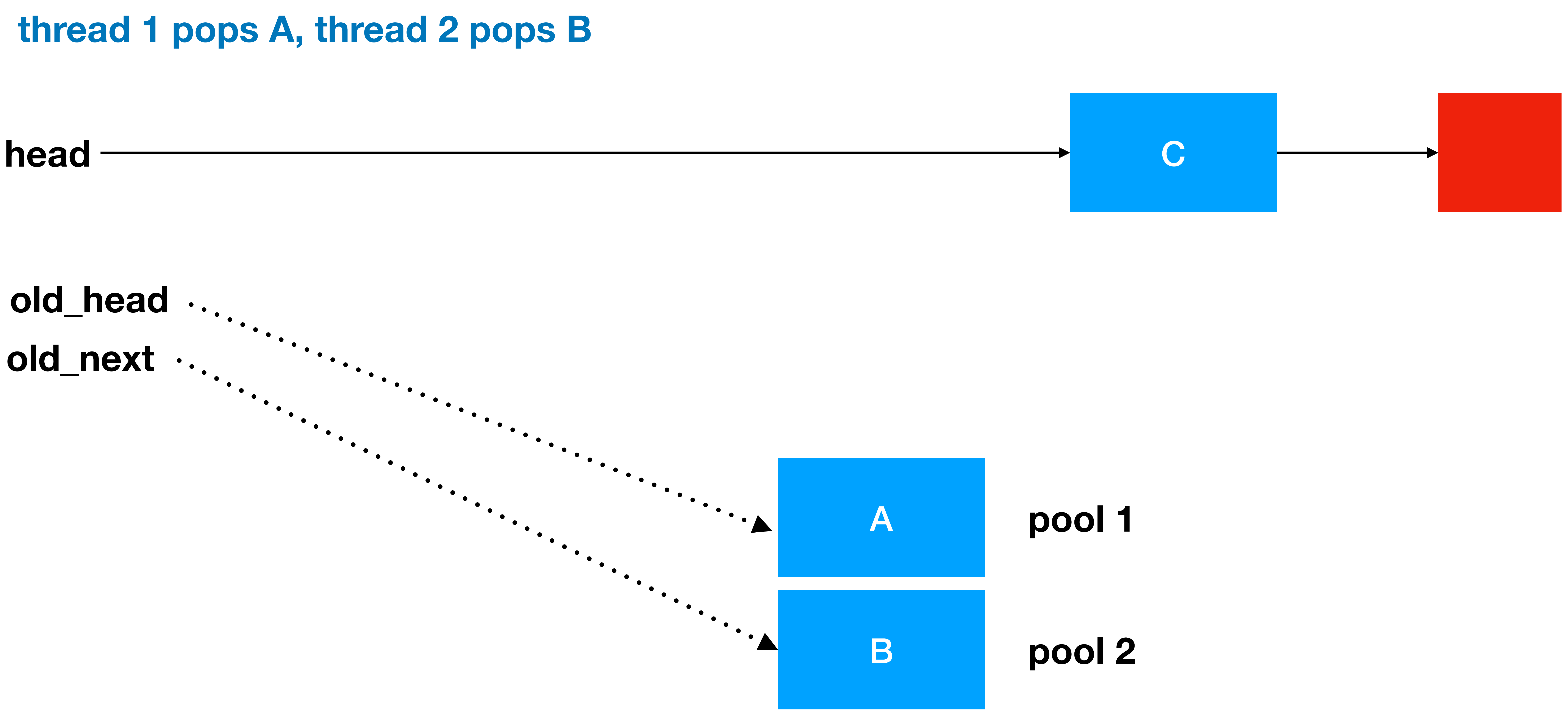
- List elements can be re-used
  - Memory is limited, pointers can reappear => still low risk
  - Improve performance by keeping a **pool** of unused list elements => much greater risk of re-use!
- What if a list element is
  - popped,
  - pushed (with new content),
  - during the non-atomic part of a Pop?

ABA problem

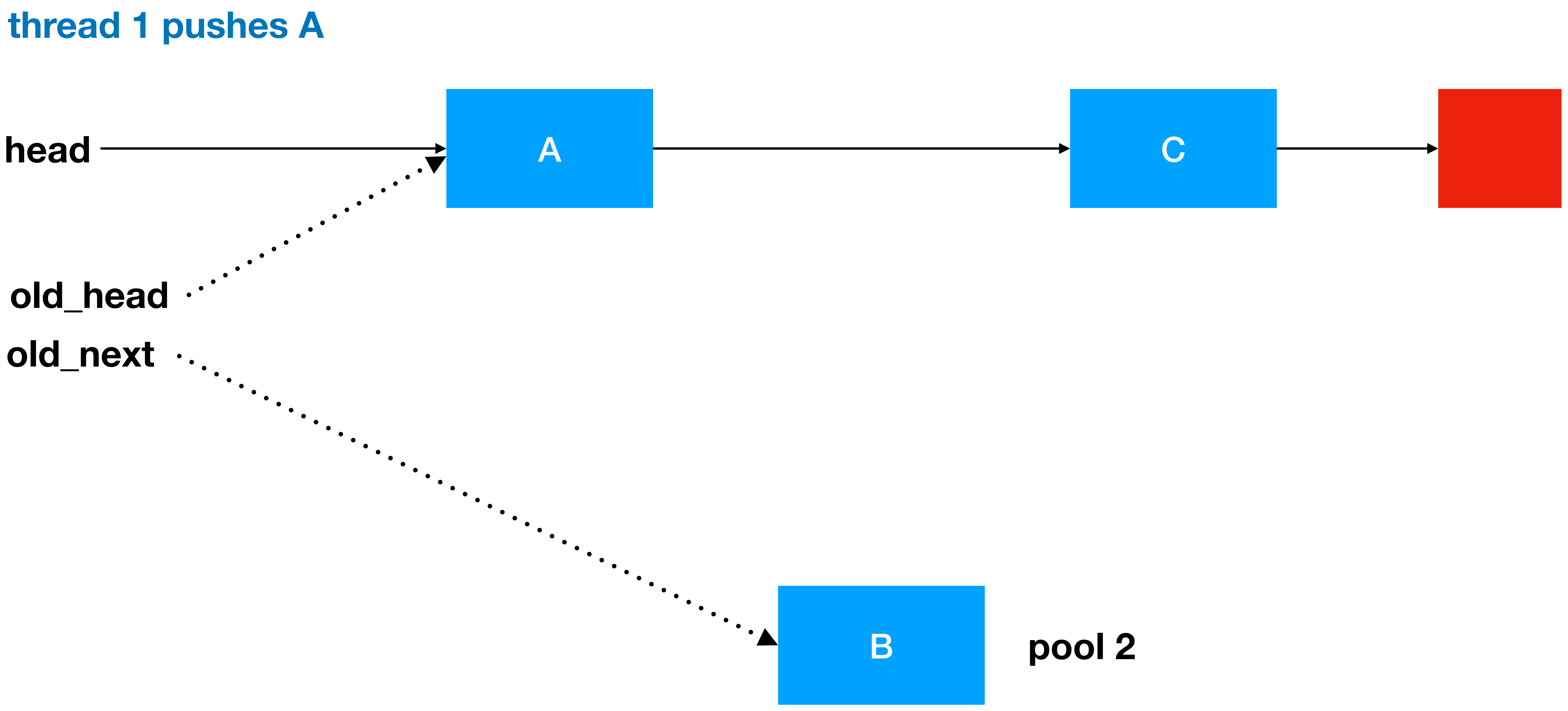
thread 0 starting pop



ABA problem

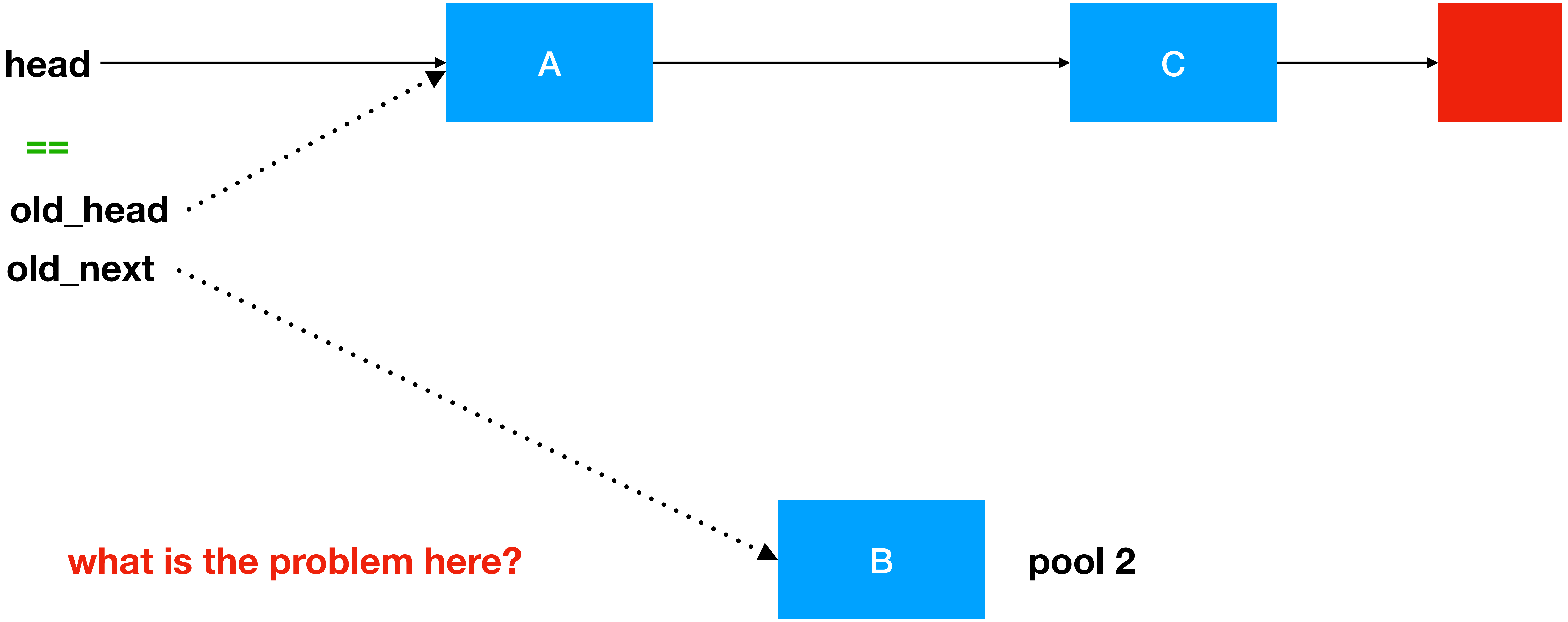

thread 1 pops A, thread 2 pops B
head
C
old_head
old_next
A
pool 1
B
pool 2

ABA problem



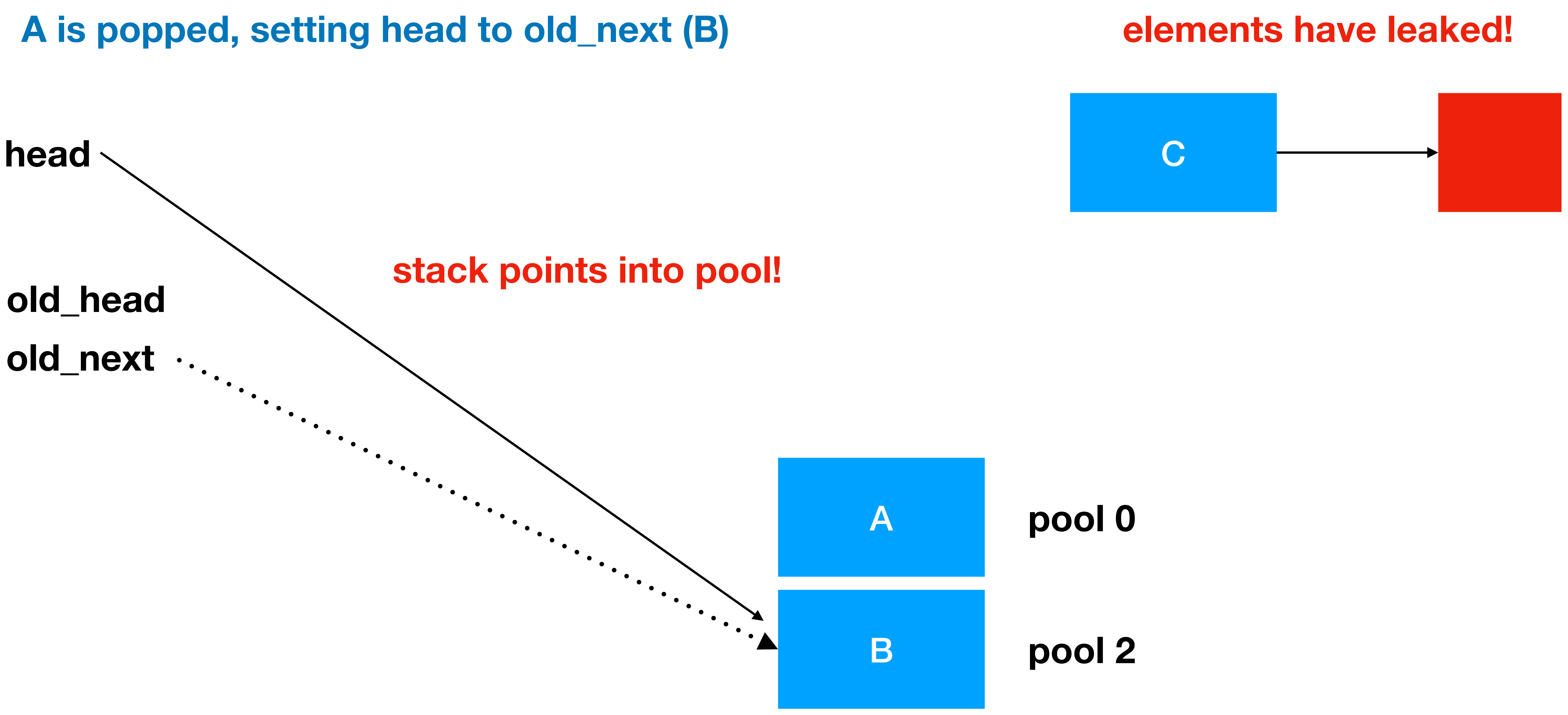
ABA problem

thread 0 resumes pop; enters atomic region:
compares head and old_head



what is the problem here?

ABA problem



A is popped, setting head to old_next (B)
elements have leaked!
head
C
stack points into pool!
old_head
old_next
A
pool 0
B
pool 2

Lab 2

- Goal for the lab:
  - Implement non-blocking unbounded stack with custom memory allocator
    - Use atomic operations
  - Study the ABA problem
    - Detect it or force it to occur
    - Can it be avoided?

Questions?