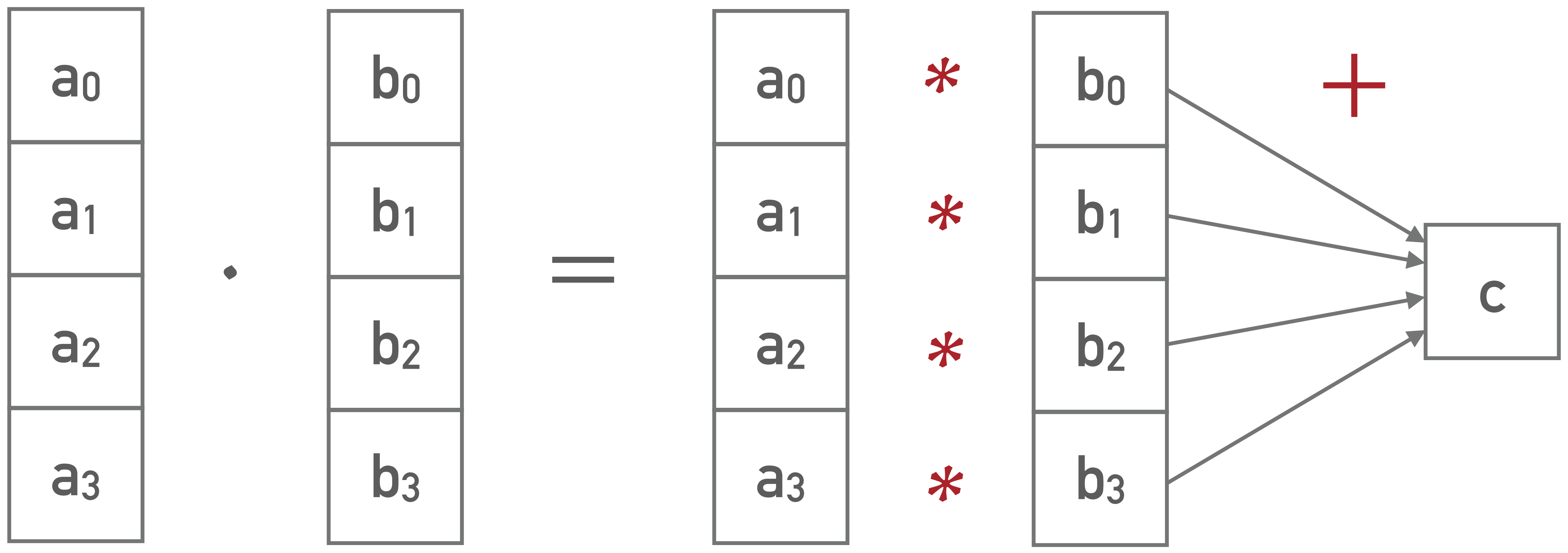
ME 471/571

Week 13 - Shared memory and thread synchronization

THREADS SYNCHRONIZATION

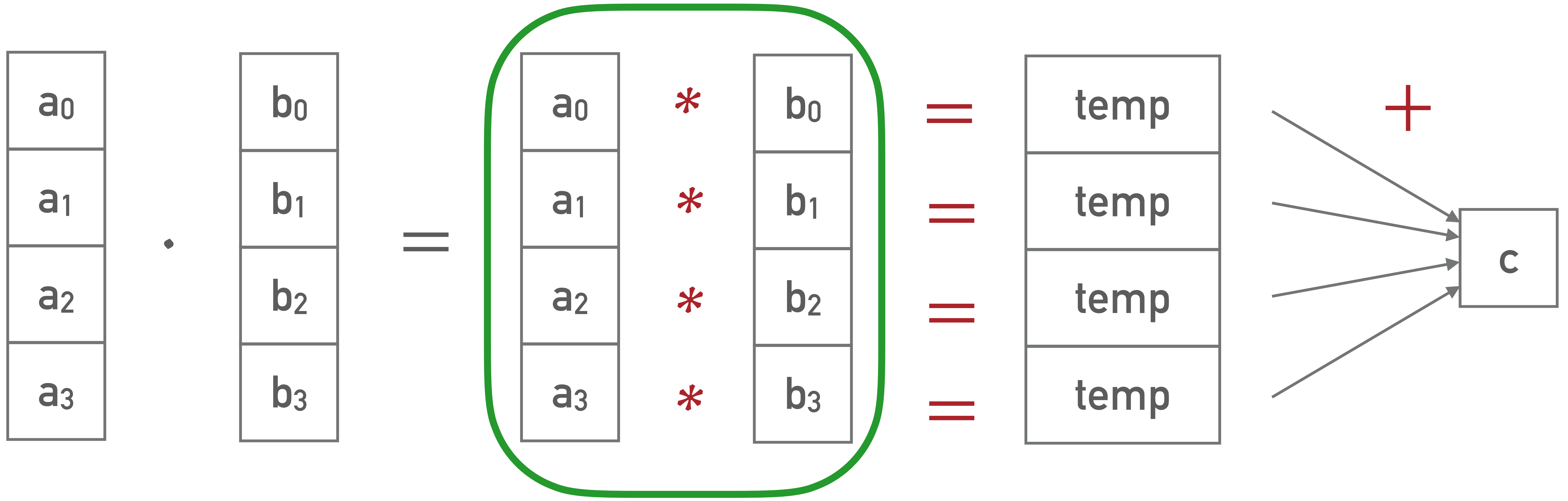
Consider a computation of dot product:




```
void dotProduct(float *A, float *B, float *C, const int N)
for (int idx = 0; idx < N; idx++)
    *C += A[idx] * B[idx];
```

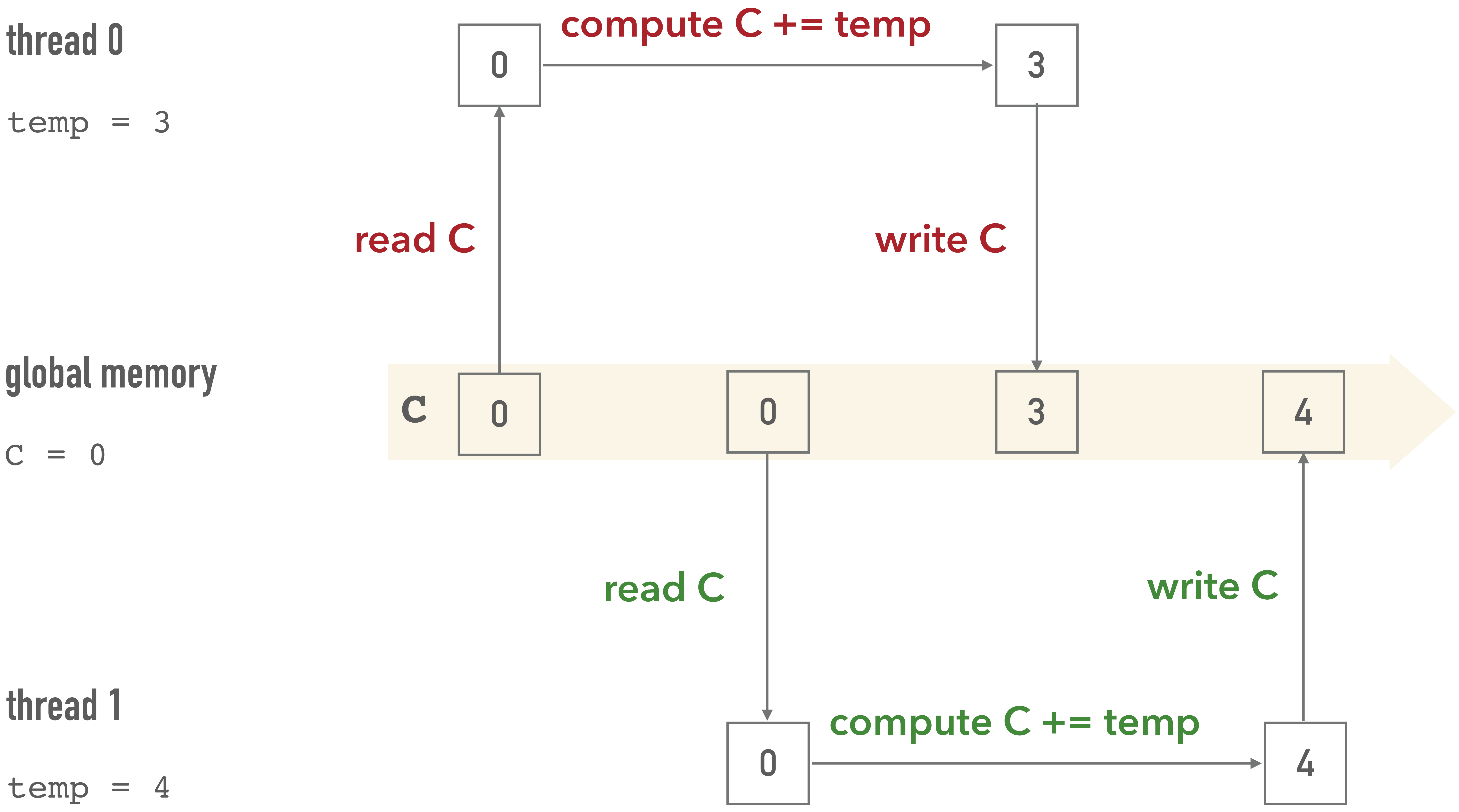
THREADS SYNCHRONIZATION

Parallel threads have no problem with the multiplication part:



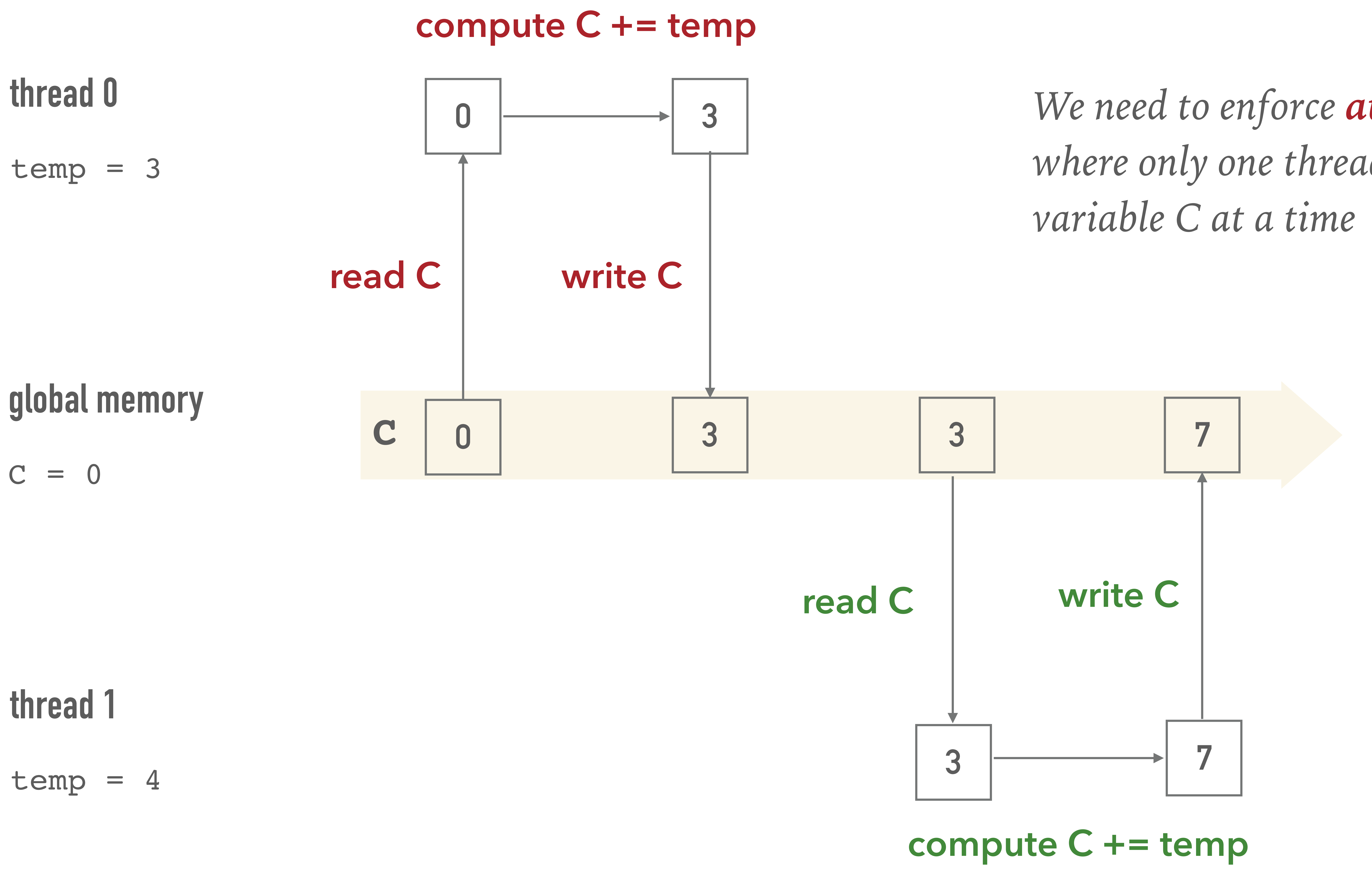

```
__global__ void dot( float *a, float *b, float *c, int N ) {
    int idx = blockIdx.x * blockDim.x + threadIdx.x;
    // Each thread computes a pairwise product
    float temp = a[idx] * b[idx];
    c += temp;
}
```

DATA RACE CONDITION



We cannot guarantee when each thread will read the memory, which leads to the ***data race condition.***

DATA RACE CONDITION



We need to enforce ***atomic operation****, where only one thread get's access to variable C at a time*

ATOMIC OPERATIONS

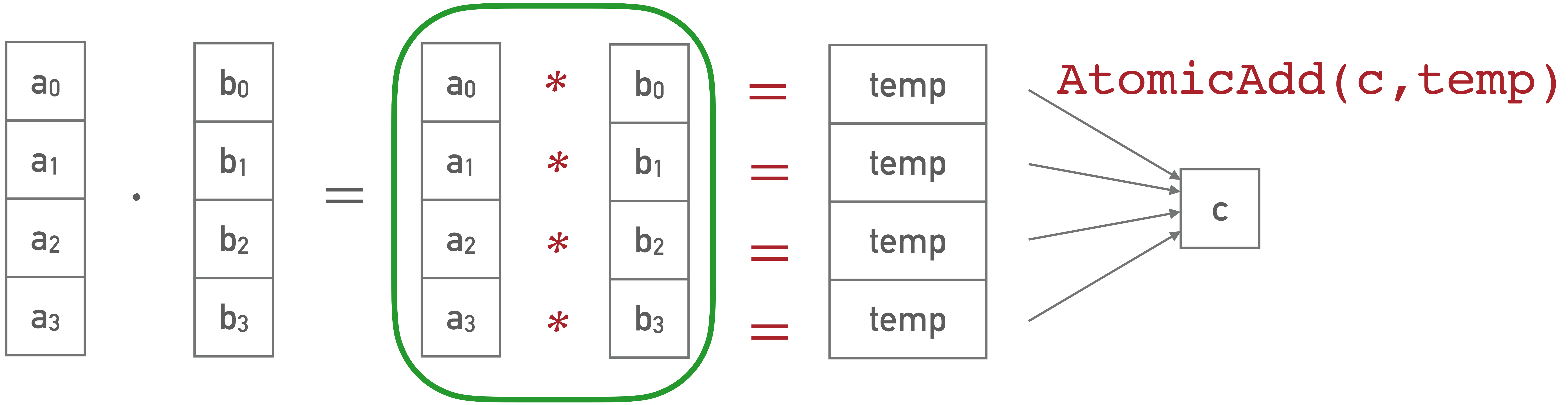
Atomic operations ensure that only one thread can access and modify a memory location. Other threads need to wait until atomic operation is completed.

atomicAdd	*addition*
atomicSub	*subtraction*
atomicMin	*minimum*
atomicMax	*maximum*
atomicInc	*increment*
atomicDec	*decrement*
atomicExch	*exchange*
atomicCAS	*compare and swap*

atomicAdd_block	*atomic with respect to block only*
atomicAdd_system	*atomic with respect to GPU and CPU (for unified memory)*

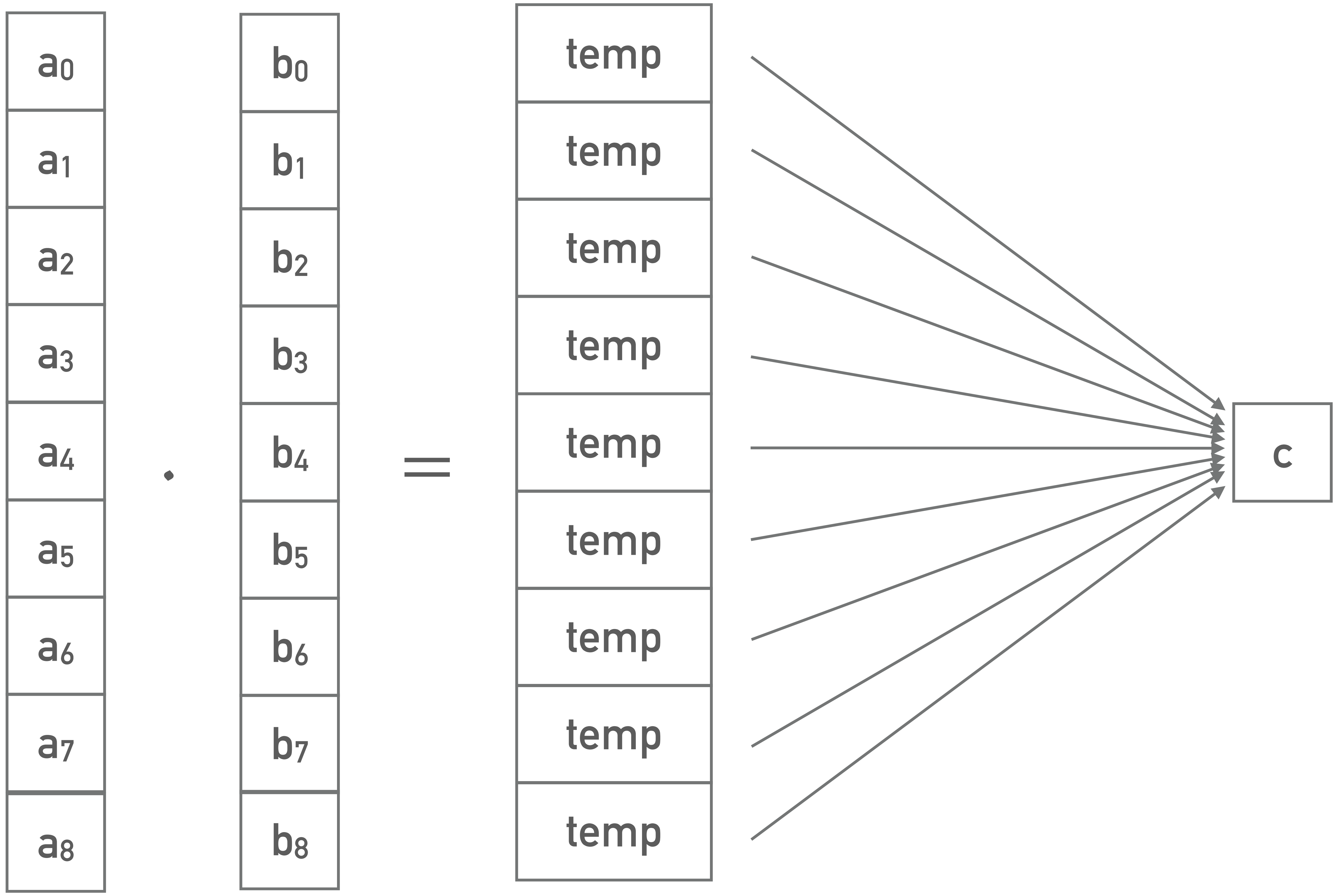
THREADS SYNCHRONIZATION

Parallel threads have no problem with the multiplication part:

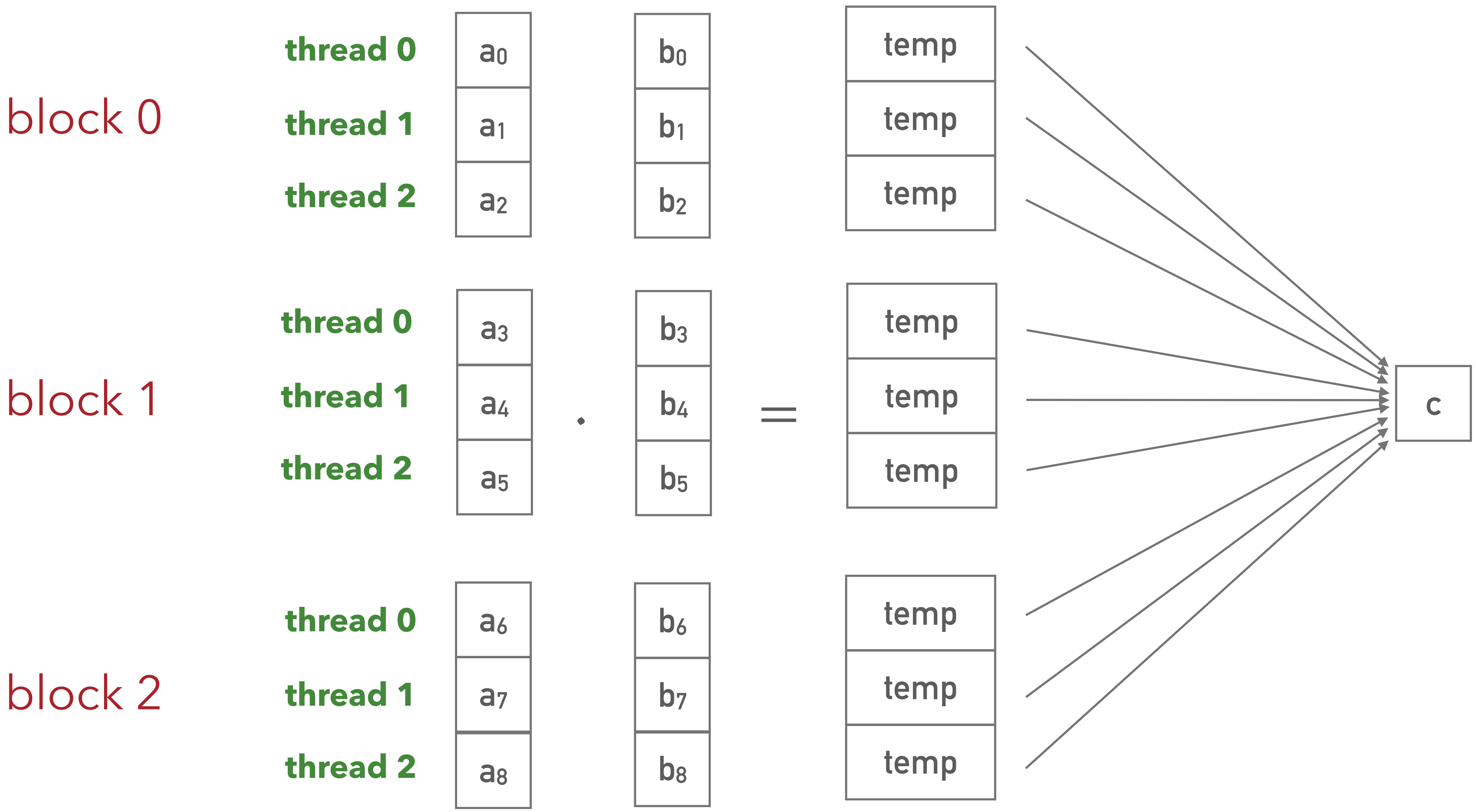



```
__global__ void dot( float *a, float *b, float *c, int N ) {
    int idx = blockIdx.x * blockDim.x + threadIdx.x;
    // Each thread computes a pairwise product
    float temp += a[idx] * b[idx];
    AtomicAdd(c,temp);
}
```

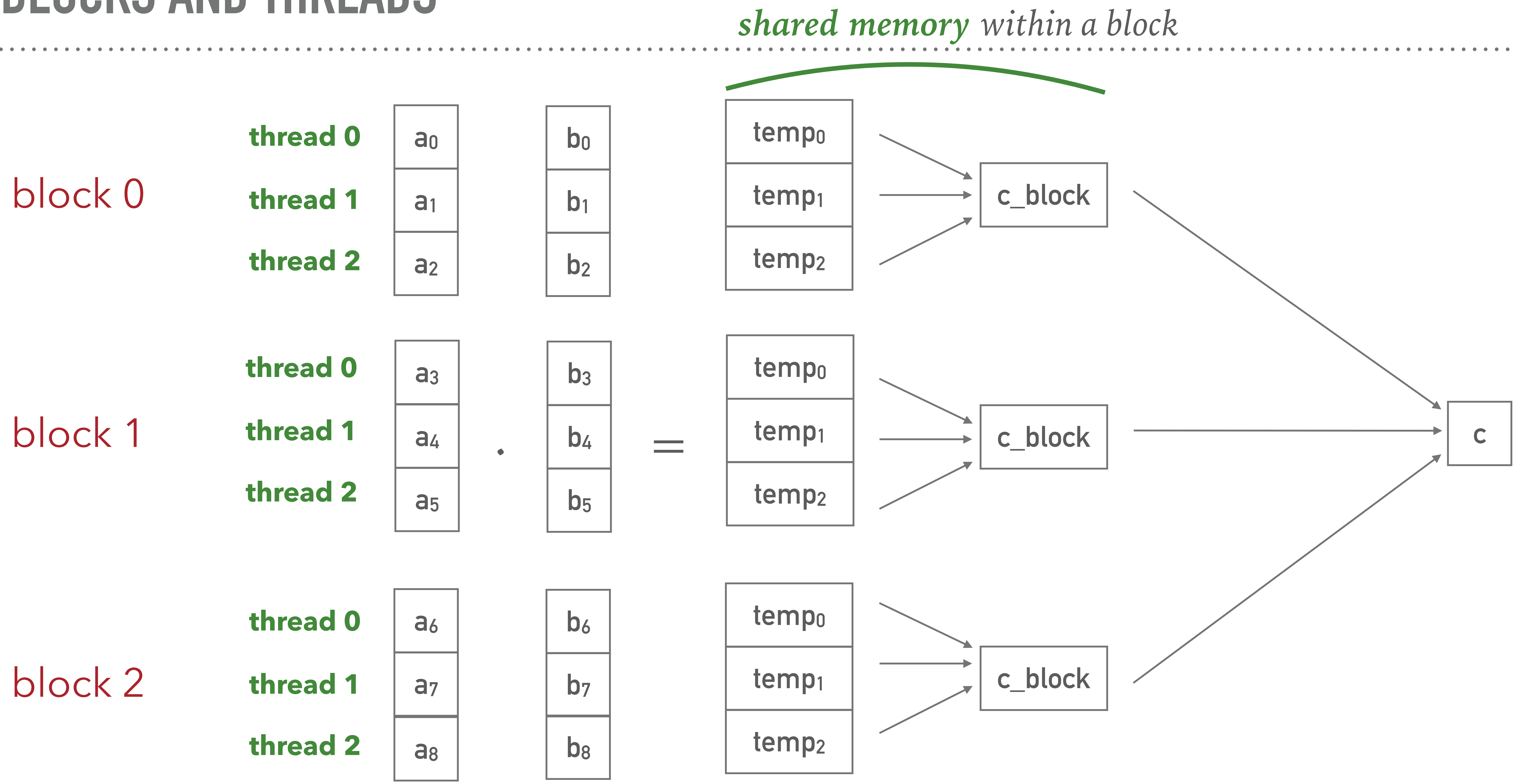
BLOCKS AND THREADS



BLOCKS AND THREADS



BLOCKS AND THREADS



THREADS SYNCHRONIZATION

Shared memory:

- is shared among the threads, but private to each block
- is extremely fast (think cache, but shared among threads)

```
__global__ void dot( int *a, int *b, int *c, int N  ) {
    int idx = blockIdx.x * blockDim.x + threadIdx.x;
// Each thread computes a pairwise product
    __shared__ int temp[THREADS_PER_BLOCK];
    temp[threadIdx.x] = a[idx] * b[idx];
}
```

THREADS SYNCHRONIZATION

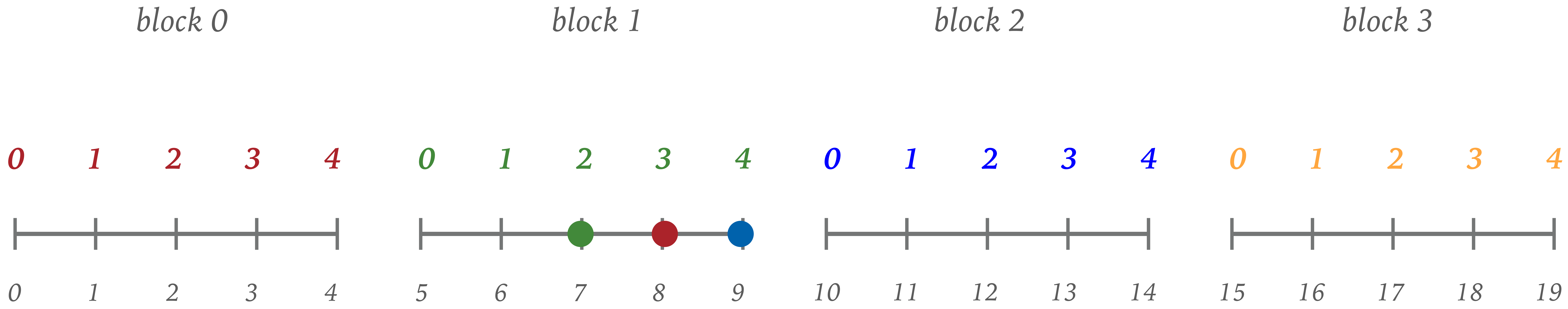
```
__global__ void dot( int *a, int *b, int *c, int N  ) {
    int idx = blockIdx.x * blockDim.x + threadIdx.x;
// Each thread computes a pairwise product
    __shared__ int temp[TREADS_PER_BLOCK];
    temp[threadIdx.x] = a[idx] * b[idx];

    __syncthreads();

    // Thread 0 sums up the pairwise products
    if(threadIdx.x == 0) {
        float block_c = 0;
        for (int i = 0; i<N; i++)
            block_c += temp[i];
        atomicAdd(c,block_c);
    }
```

FINITE DIFFERENCE ON GPUS

$$\frac{\partial u}{\partial x} \approx \frac{u_{i+1} - u_{i-1}}{2\Delta x}$$



FINITE DIFFERENCE ON GPUS

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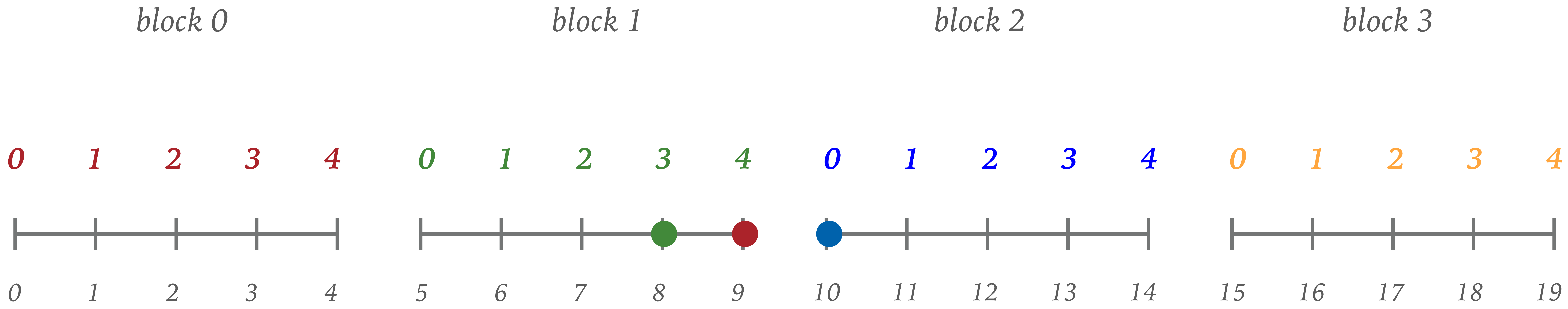

this is fine, since we have global memory

FINITE DIFFERENCE ON GPUS

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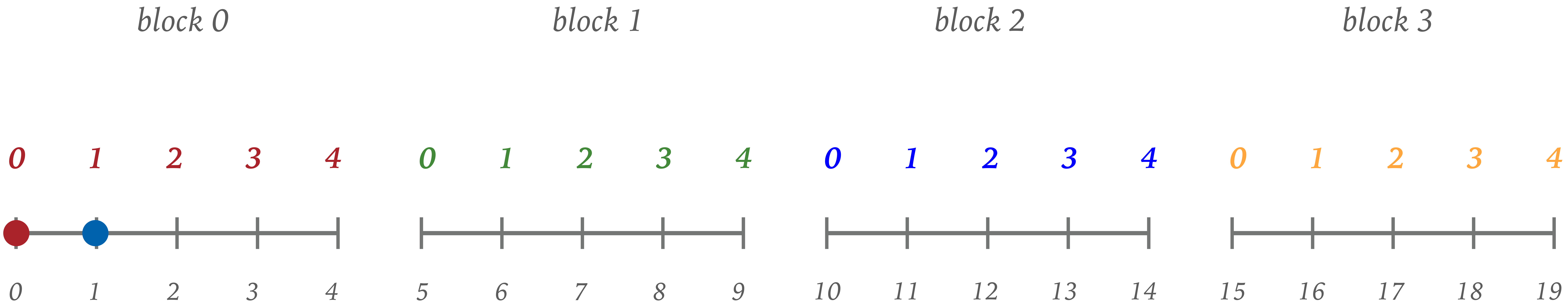
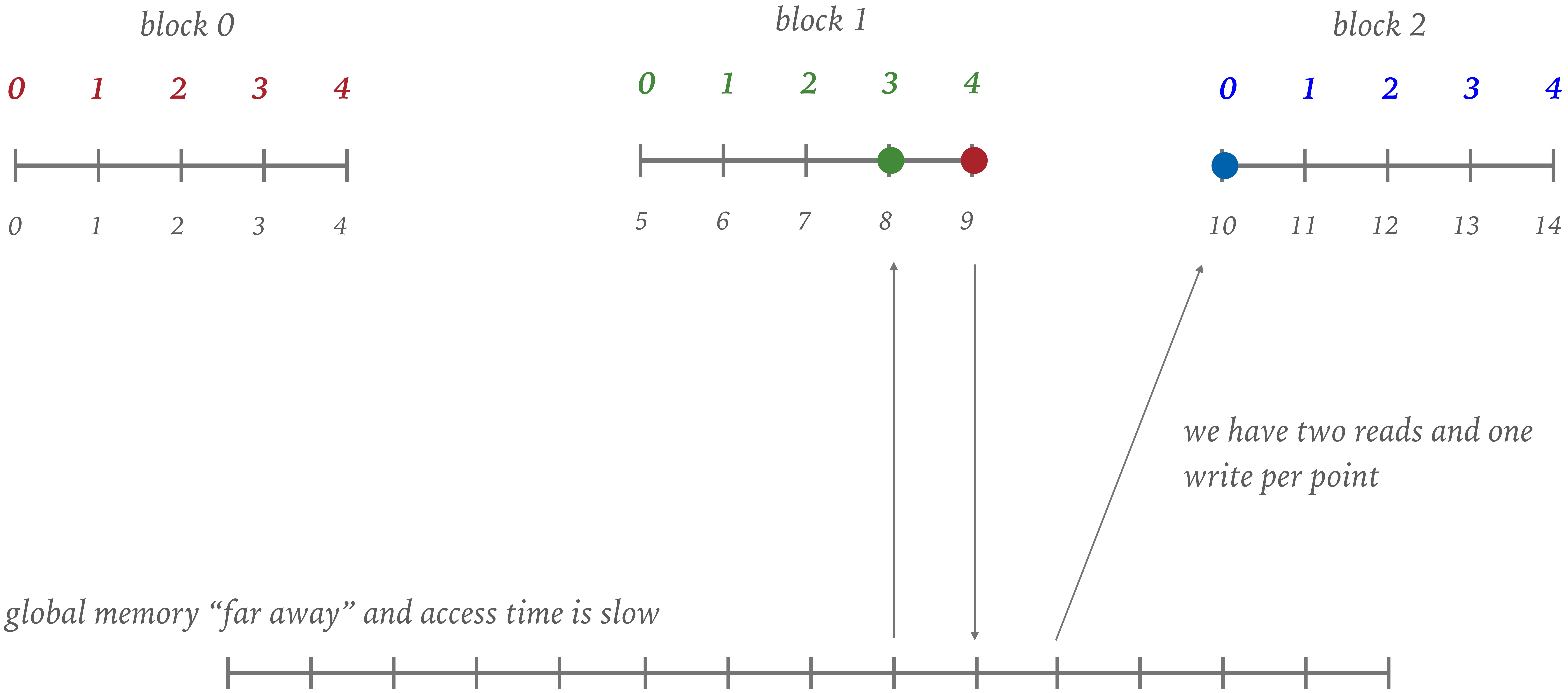
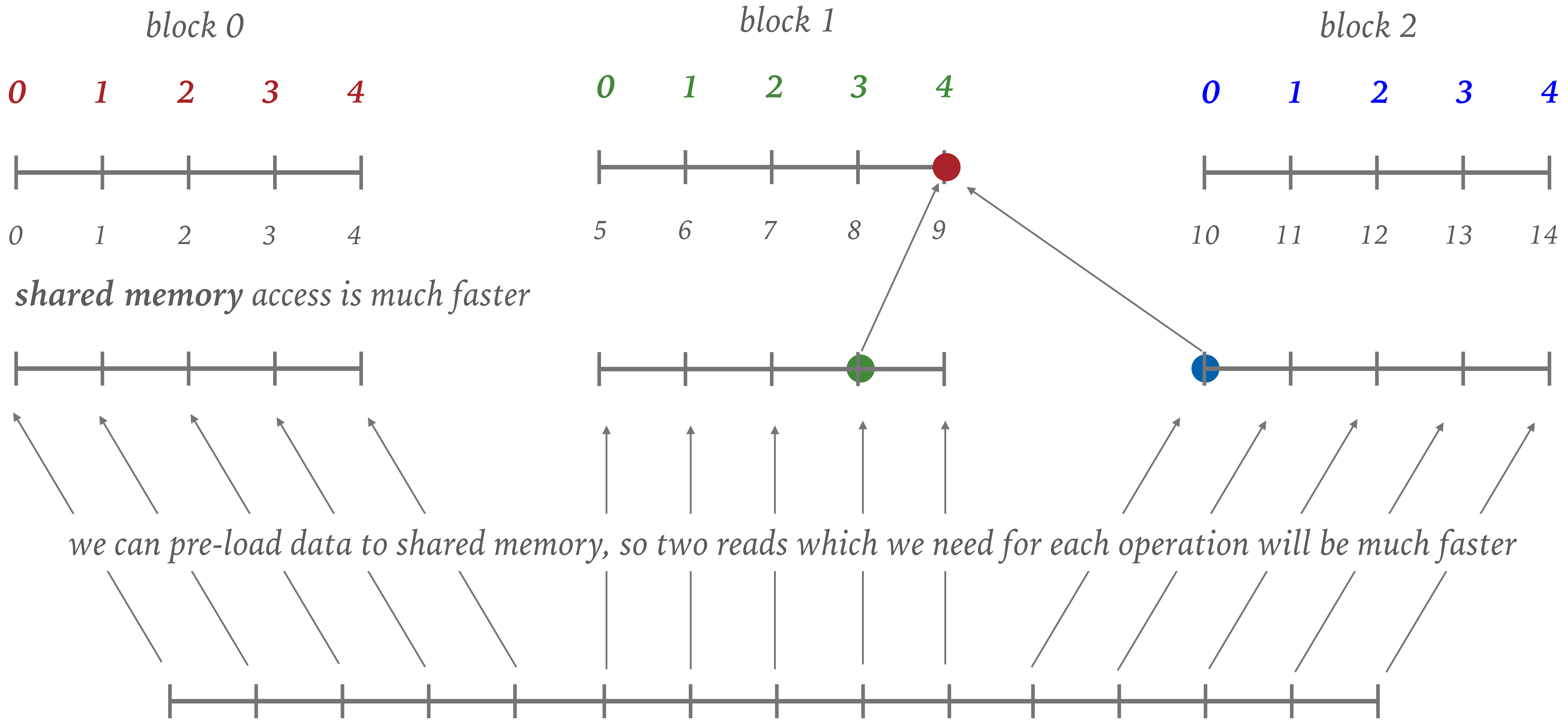


we need to do boundary points using one-sided difference, as usual

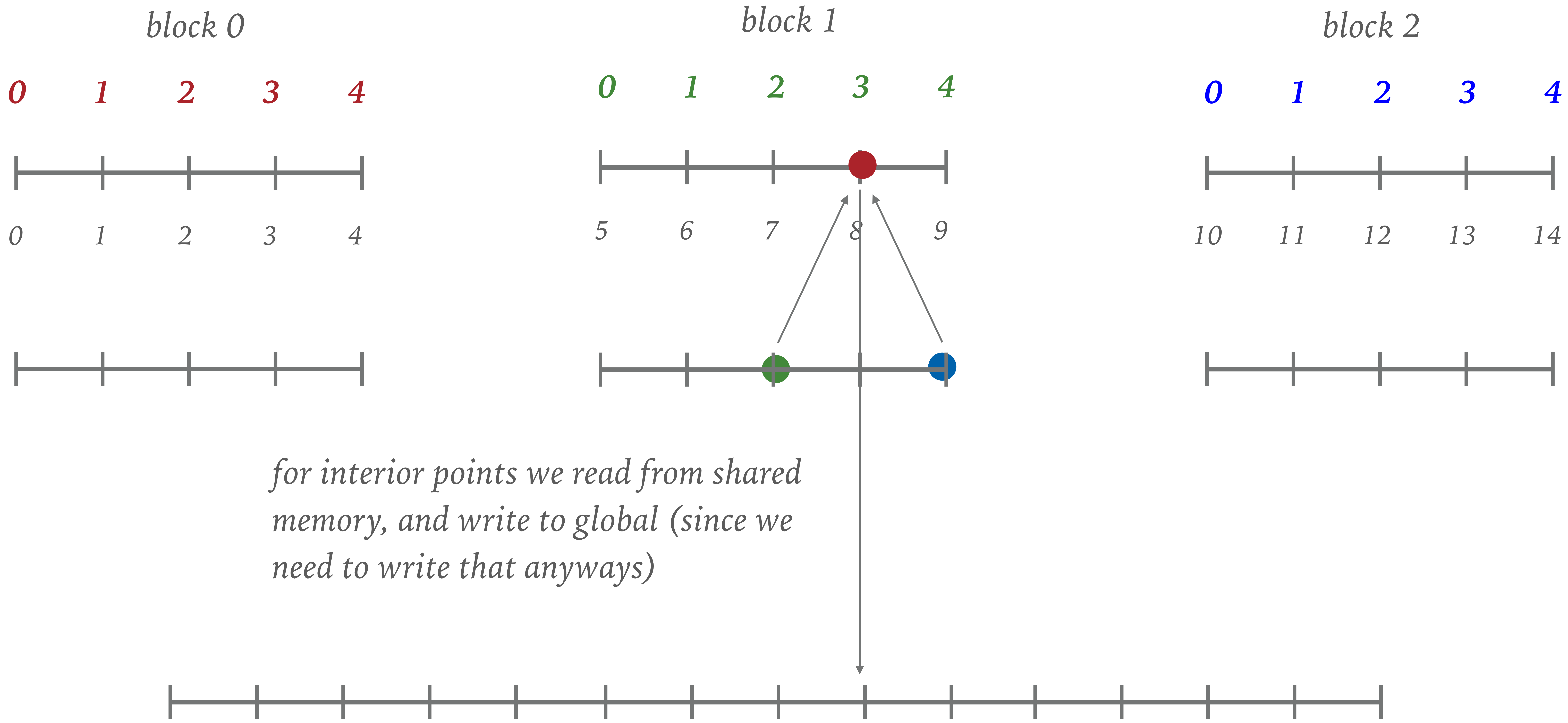
FINITE DIFFERENCE ON GPUS – SHARED MEMORY



FINITE DIFFERENCE ON GPUS – SHARED MEMORY

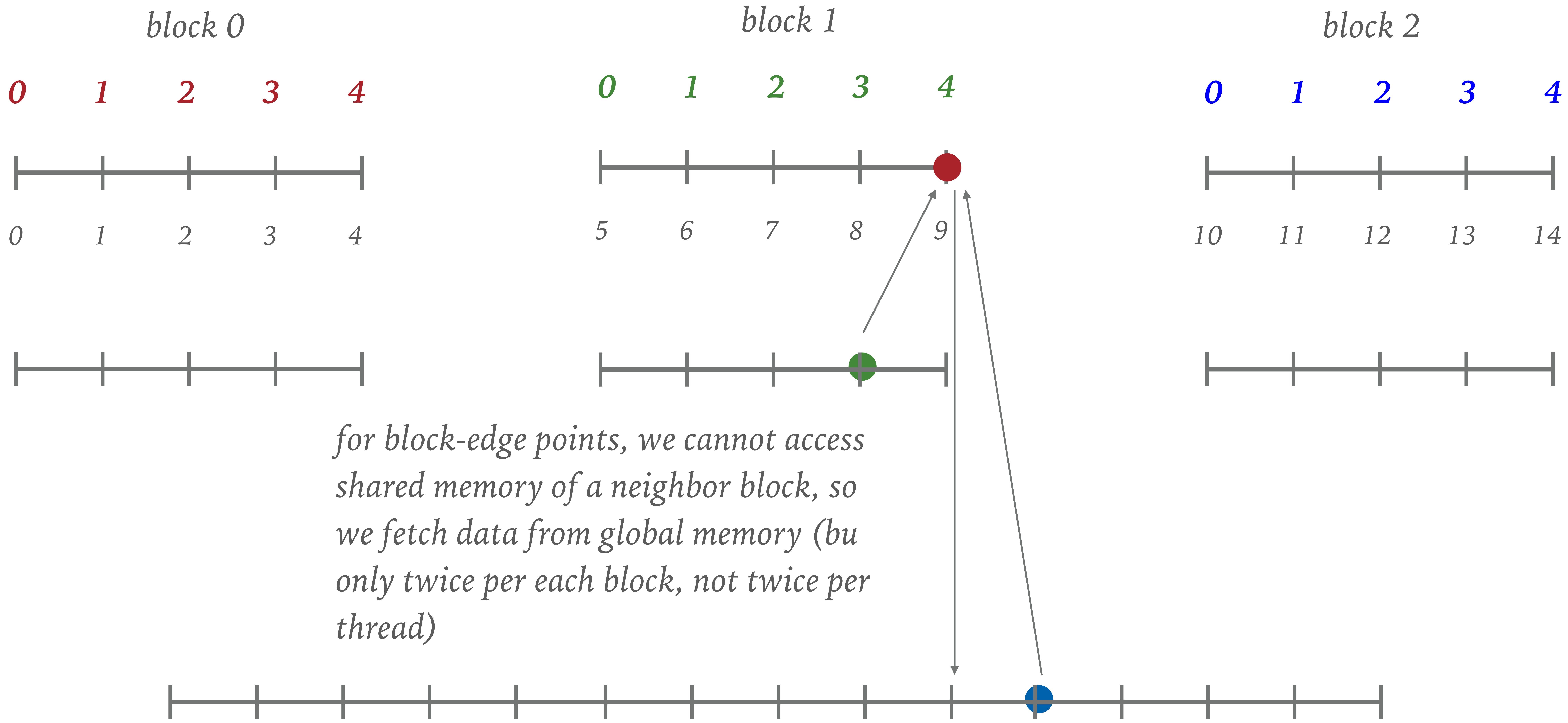


FINITE DIFFERENCE ON GPUS – SHARED MEMORY



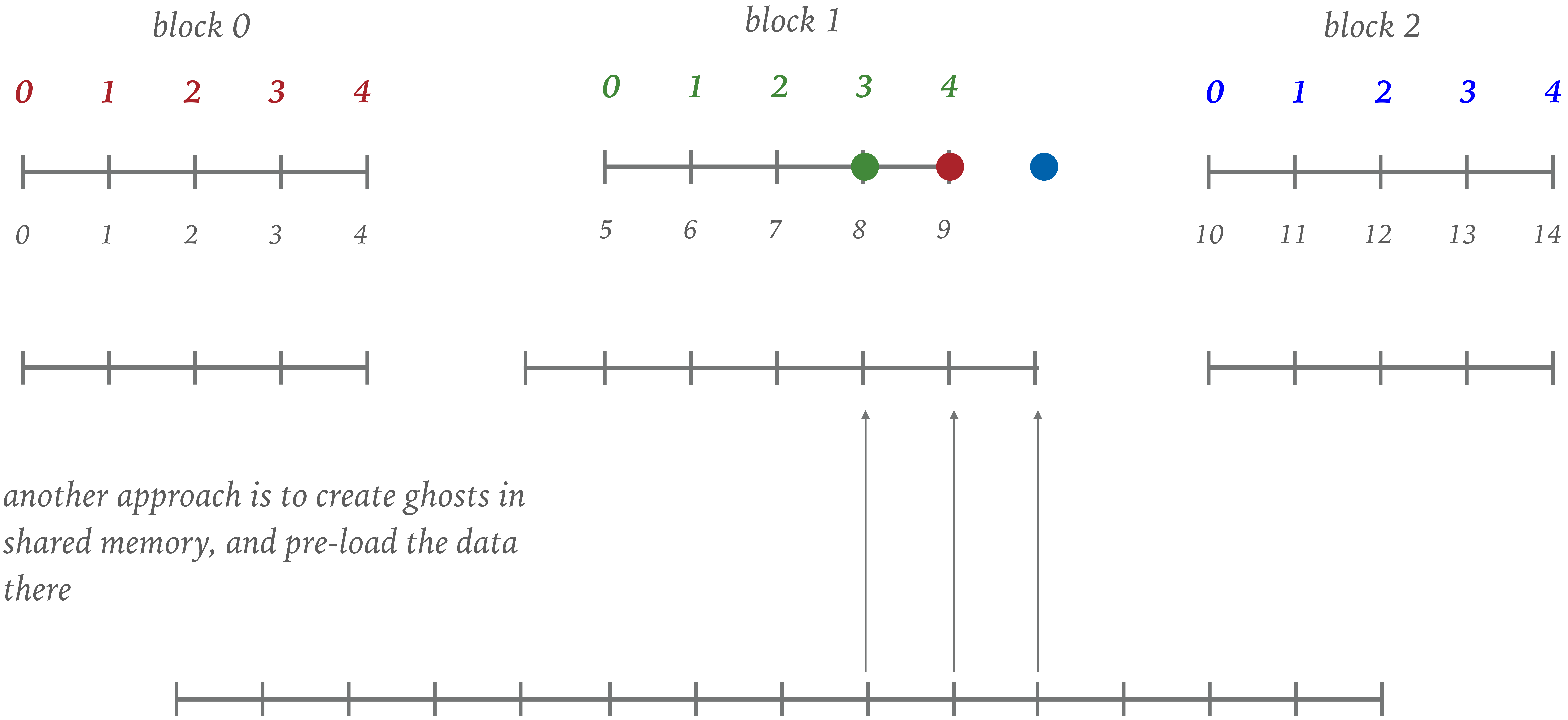
for interior points we read from shared memory, and write to global (since we need to write that anyways)

FINITE DIFFERENCE ON GPUS – SHARED MEMORY



for block-edge points, we cannot access shared memory of a neighbor block, so we fetch data from global memory (bu only twice per each block, not twice per thread)

FINITE DIFFERENCE ON GPUS - SHARED MEMORY - GHOSTS



another approach is to create ghosts in shared memory, and pre-load the data there

FINITE DIFFERENCE ON GPUS - SHARED MEMORY - GHOSTS