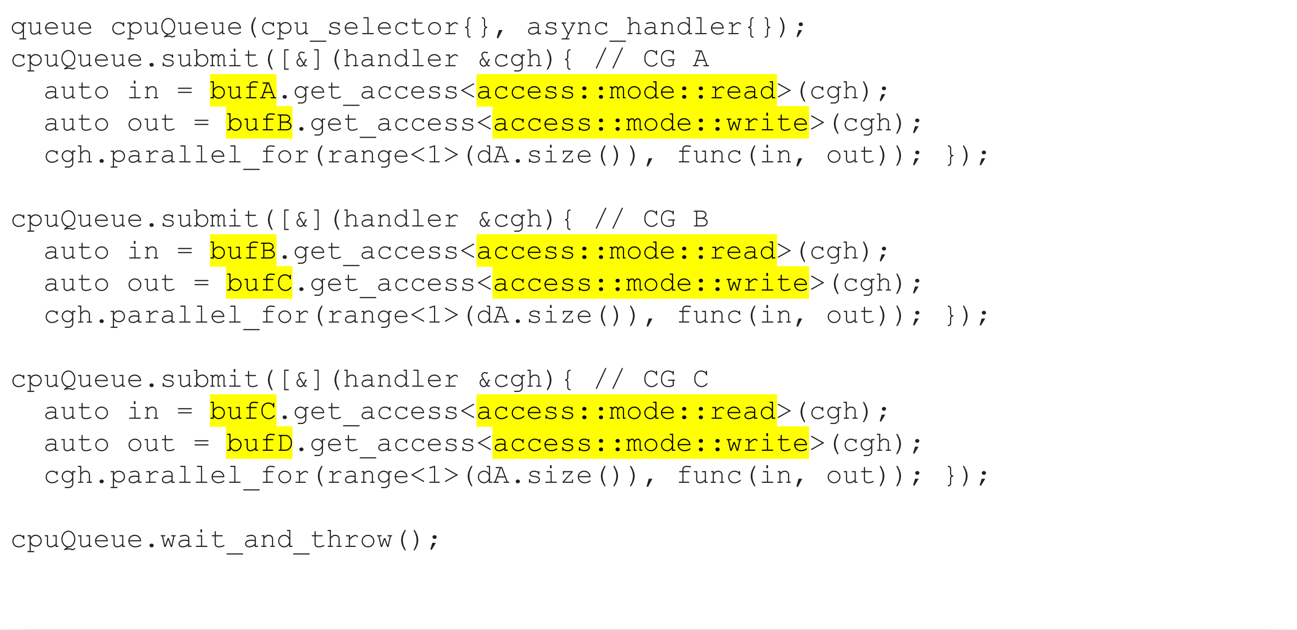
SYCL DATA DEPENDENCY ANALYSIS

LEARNING OBJECTIVES

- Learn about how the SYCL runtime orders execution using data dependencies
- Learn about how SYCL synchronizes data

- When a command group is submitted to a SYCL queue the runtime performs dependency analysis
  - If a command group requests access to a memory object, such as a buffer
    - A pre-requisite is the data must be available before kernel execution
  - The scheduler uses these pre-requisites to order the execution of commands
- Data is copied when required or when explicitly requested
  - Data will stay on the device to avoid unnecessary copies back to the host

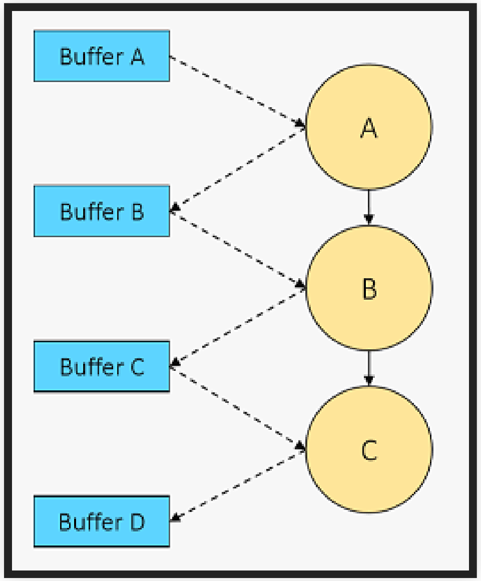


```
queue cpuQueue(cpu_selector{}, async_handler{});
cpuQueue.submit([&](handler &cgh){ // CG A
  auto in = bufA.get_access<access::mode::read>(cgh);
  auto out = bufB.get_access<access::mode::write>(cgh);
  cgh.parallel_for(range<1>(dA.size()), func(in, out)); });

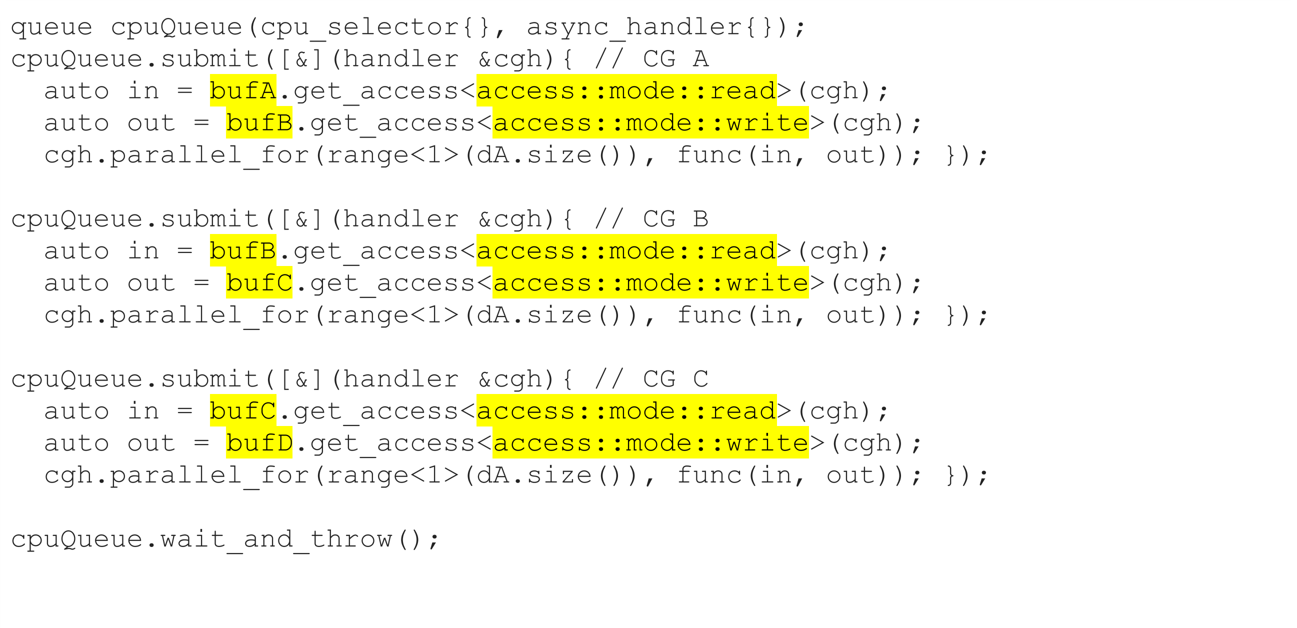
cpuQueue.submit([&](handler &cgh){ // CG B
  auto in = bufB.get_access<access::mode::read>(cgh);
  auto out = bufC.get_access<access::mode::write>(cgh);
  cgh.parallel_for(range<1>(dA.size()), func(in, out)); });

cpuQueue.submit([&](handler &cgh){ // CG C
  auto in = bufC.get_access<access::mode::read>(cgh);
  auto out = bufD.get_access<access::mode::write>(cgh);
  cgh.parallel_for(range<1>(dA.size()), func(in, out)); });

cpuQueue.wait_and_throw();
```



- To use a C++ function object you simply construct an instance of the type initializing the accessors and pass it to parallel_for
- Notice you no longer need to name the SYCL kernel



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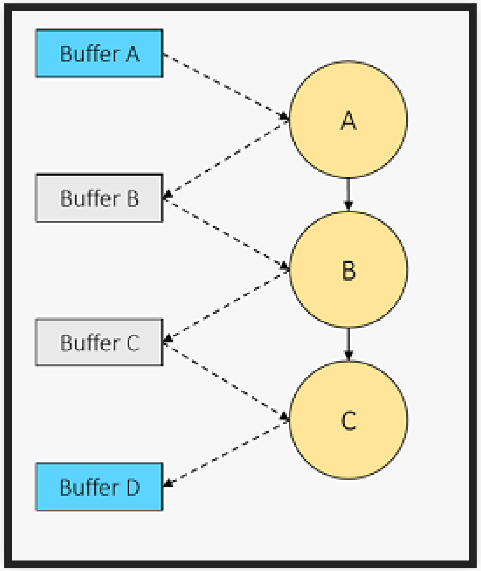
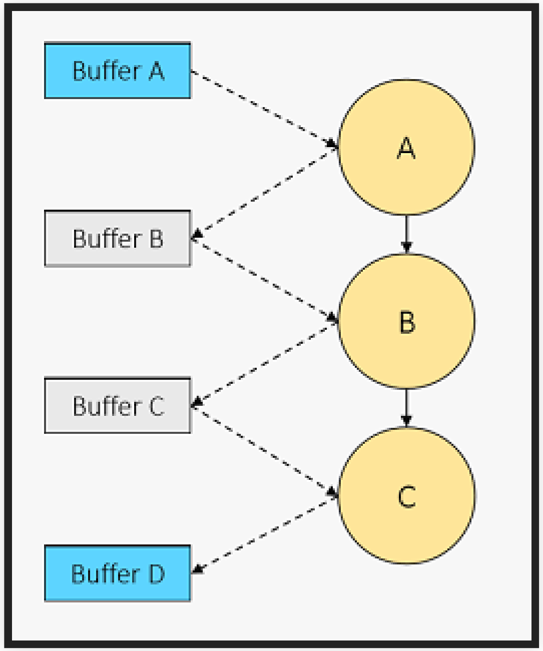
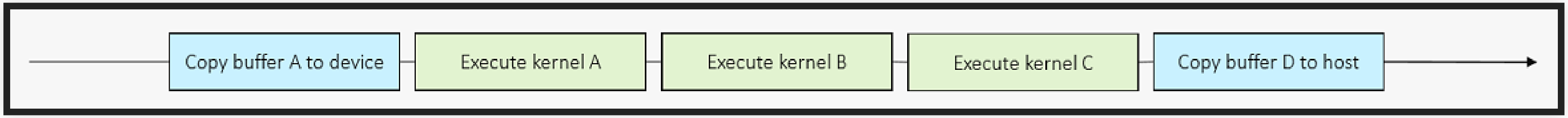


Buffers B and C are not accessed on the host so they can be optimized to remain on the device



- As these commands are required to execute in sequence, they are enqueued to OpenCL with events between each one
- There are no copies required for buffers B and C as they remain on the device



Copy buffer A to device → Execute kernel A → Execute kernel B → Execute kernel C → Copy buffer D to host

```
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cpuQueue.submit([&](handler &cgh){ // CG B
  auto in = bufB.get_access<access::mode::read>(cgh);
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cpuQueue.submit([&](handler &cgh){ // CG C
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cpuQueue.wait_and_throw();
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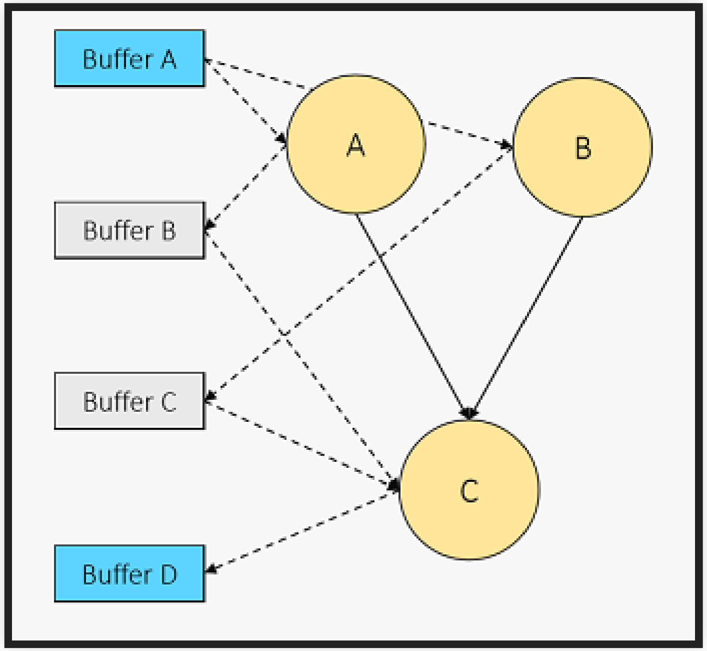
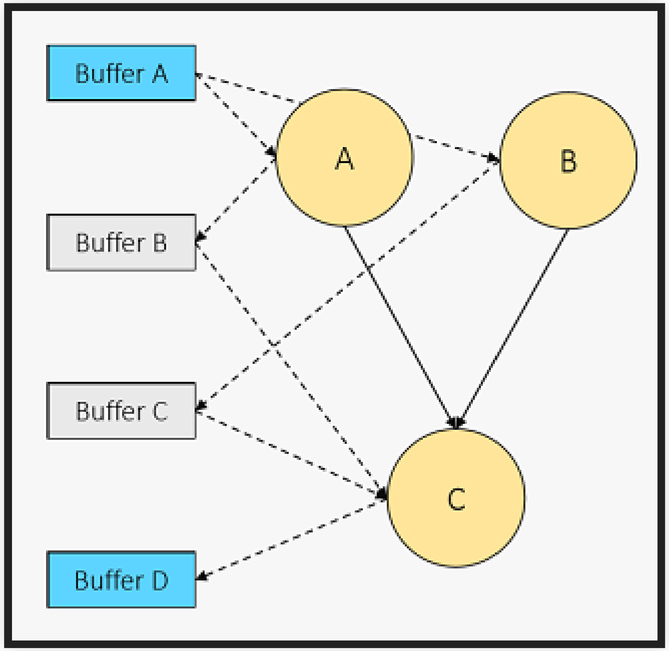
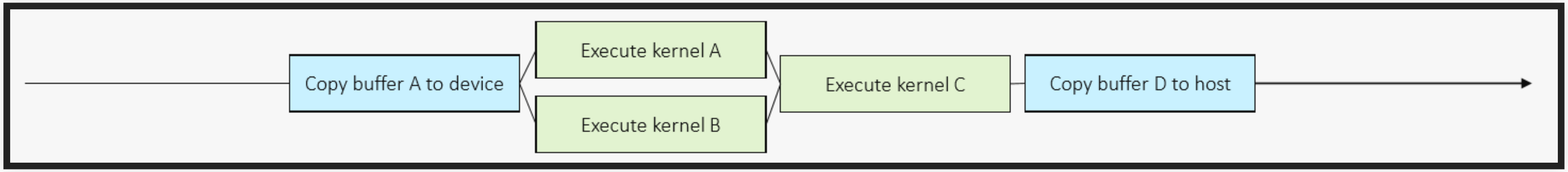


The third command group has data dependencies on the previous, the first two command groups run concurrently

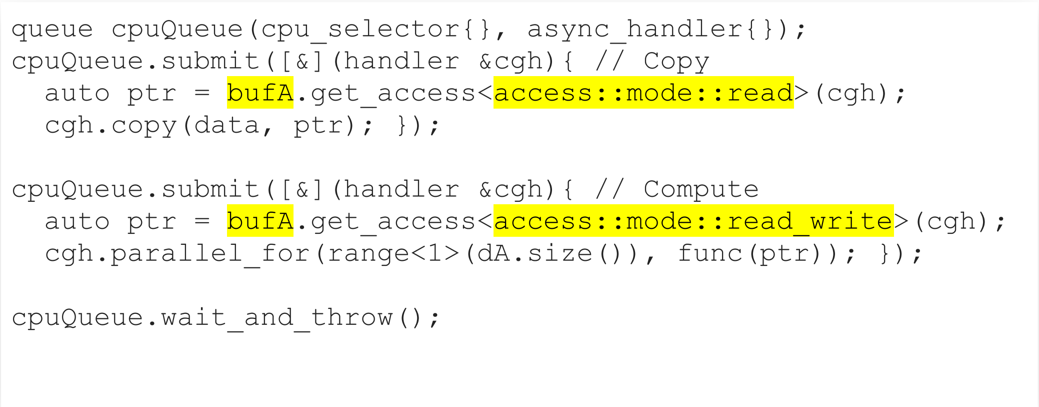


- As command groups A and B are only reading from buffer A, they can both access it concurrently
- As there are no dependencies between command groups A and B they can be run in parallel
- Again, there are no copies required for buffers B and C as they remain on the device



EXPLICIT COPY COMMANDS

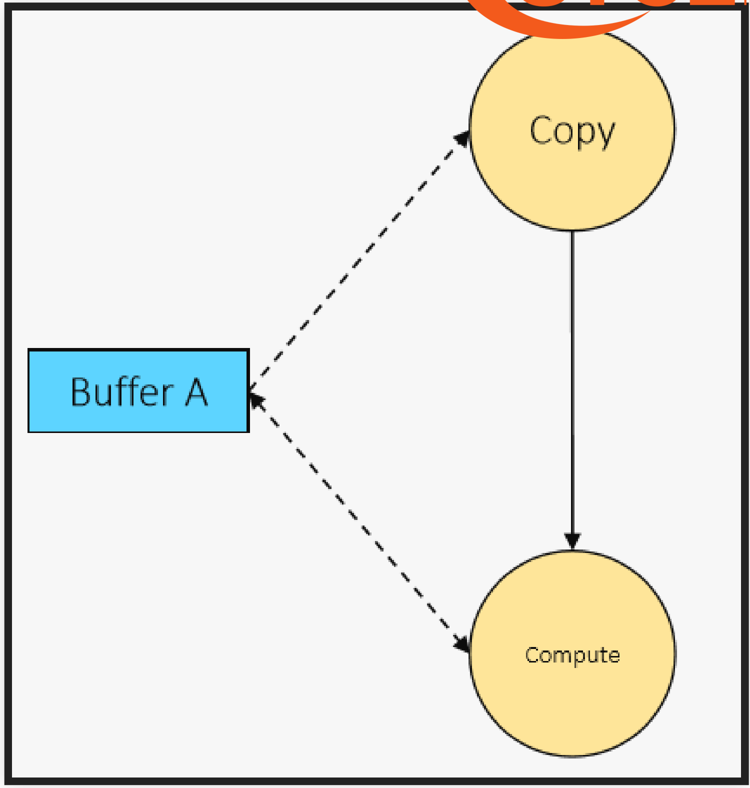
- As well as SYCL kernel functions a command group can also contain explicit copy commands
  - These commands enqueue a copy operation to the SYCL scheduler with the same data dependency analysis
  - This can be used to perform double buffering of copy and compute



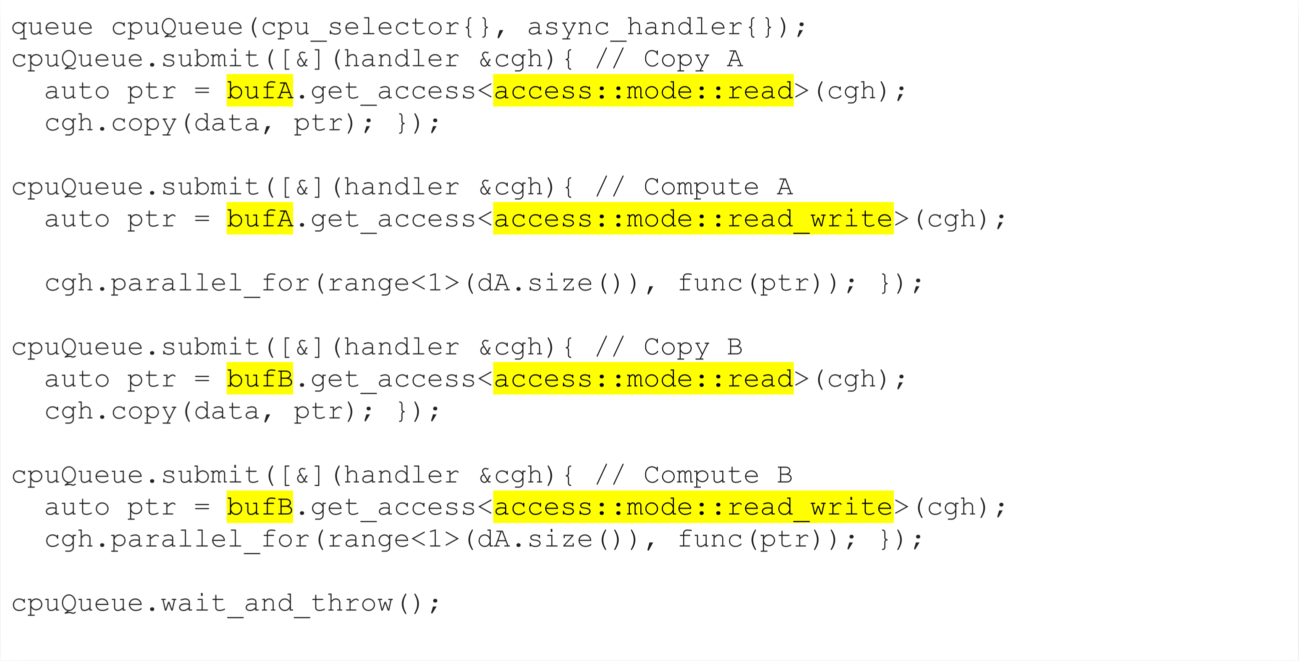
```
queue cpuQueue(cpu_selector{}, async_handler{});
cpuQueue.submit([&](handler &cgh){ // Copy
  auto ptr = bufA.get_access<access::mode::read>(cgh);
  cgh.copy(data, ptr); });

cpuQueue.submit([&](handler &cgh){ // Compute
  auto ptr = bufA.get_access<access::mode::read_write>(cgh);
  cgh.parallel_for(range<1>(dA.size()), func(ptr)); });

cpuQueue.wait_and_throw();
```



The command group performing the copy must complete before the command group performing the computation



```
queue cpuQueue(cpu_selector{}, async_handler{});
cpuQueue.submit([&](handler &cgh){ // Copy A
  auto ptr = bufA.get_access<access::mode::read>(cgh);
  cgh.copy(data, ptr); });

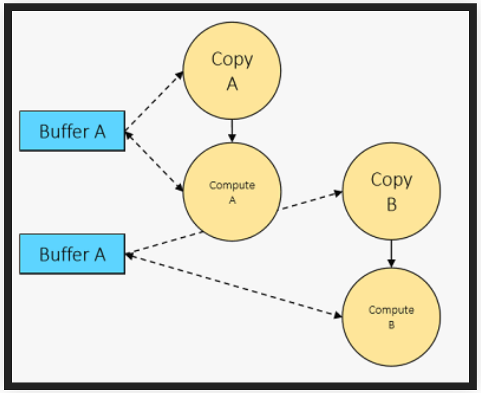
cpuQueue.submit([&](handler &cgh){ // Compute A
  auto ptr = bufA.get_access<access::mode::read_write>(cgh);

  cgh.parallel_for(range<1>(dA.size()), func(ptr)); });

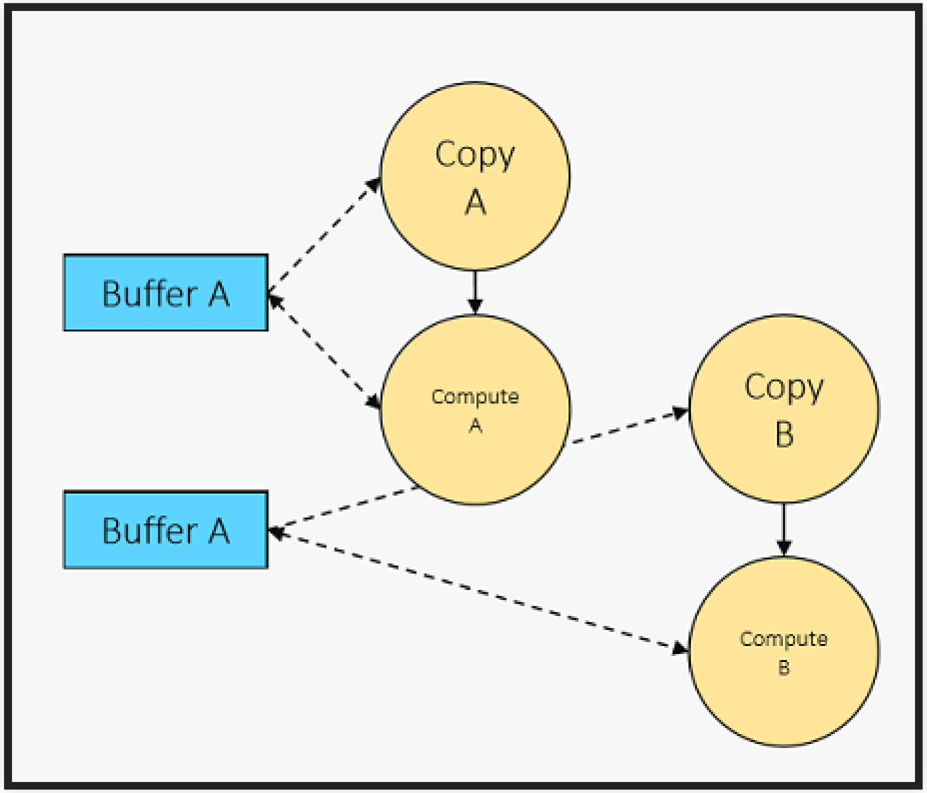
cpuQueue.submit([&](handler &cgh){ // Copy B
  auto ptr = bufB.get_access<access::mode::read>(cgh);
  cgh.copy(data, ptr); });

cpuQueue.submit([&](handler &cgh){ // Compute B
  auto ptr = bufB.get_access<access::mode::read_write>(cgh);
  cgh.parallel_for(range<1>(dA.size()), func(ptr)); });

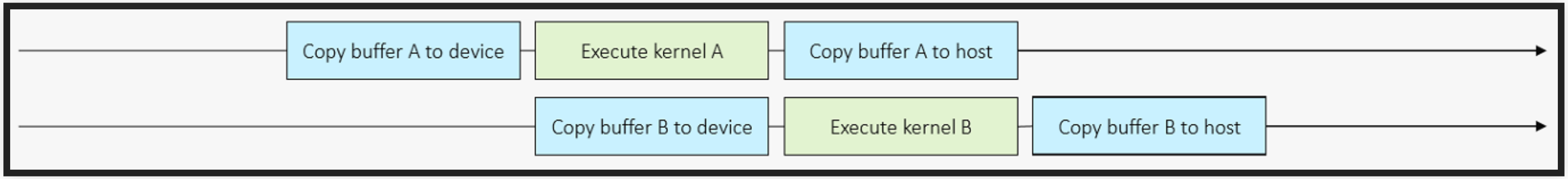
cpuQueue.wait_and_throw();
```



The command group copying buffer B can execute concurrently with the compute of buffer A

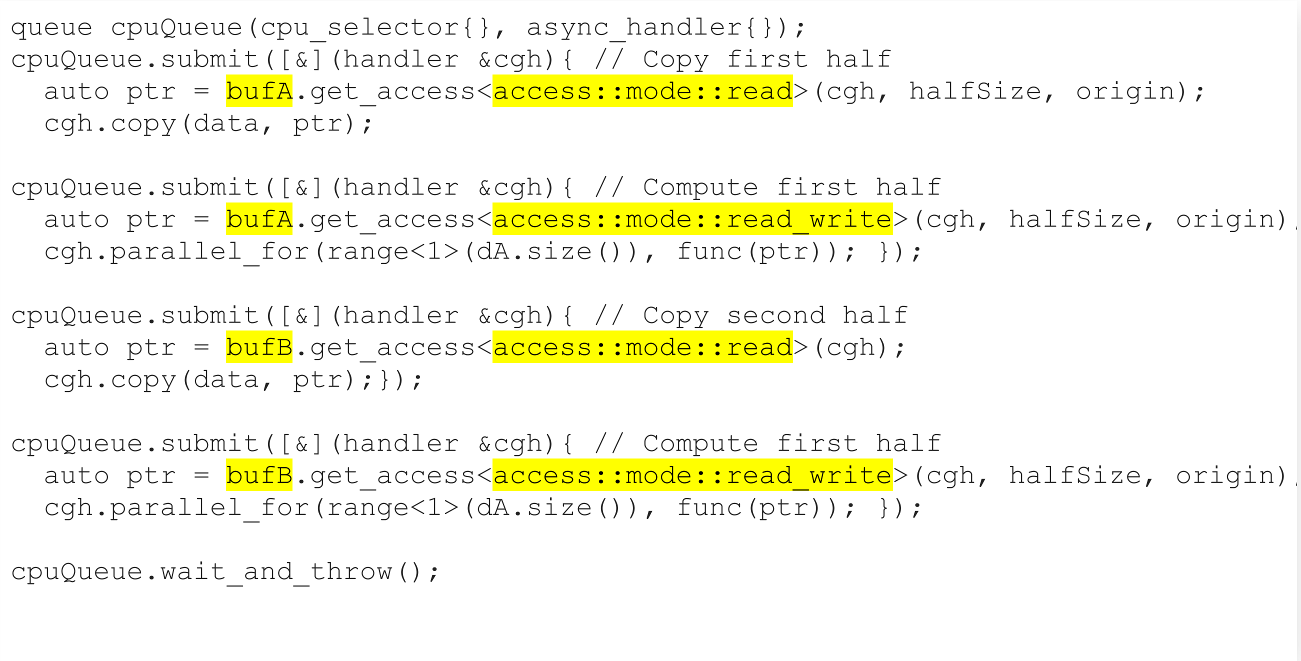


- The copy and compute on buffer A and buffer B are independent so they have separate chains of events
- This means that they can be run in parallel, double buffering copy and compute



RANGED ACCESSORS

- By default accessors access the entire buffer, however it's possible to access only a region of a buffer
  - Only the region of the buffer that you are accessing is copied
  - This is particularly useful for tiling larger data



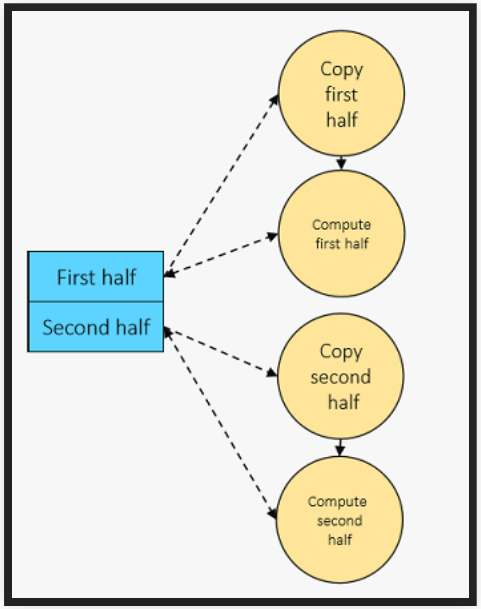
```
queue cpuQueue(cpu_selector{}, async_handler{});
cpuQueue.submit([&](handler &cgh){ // Copy first half
  auto ptr = bufA.get_access<access::mode::read>(cgh, halfSize, origin);
  cgh.copy(data, ptr);

cpuQueue.submit([&](handler &cgh){ // Compute first half
  auto ptr = bufA.get_access<access::mode::read_write>(cgh, halfSize, origin)
  cgh.parallel_for(range<1>(dA.size()), func(ptr)); });

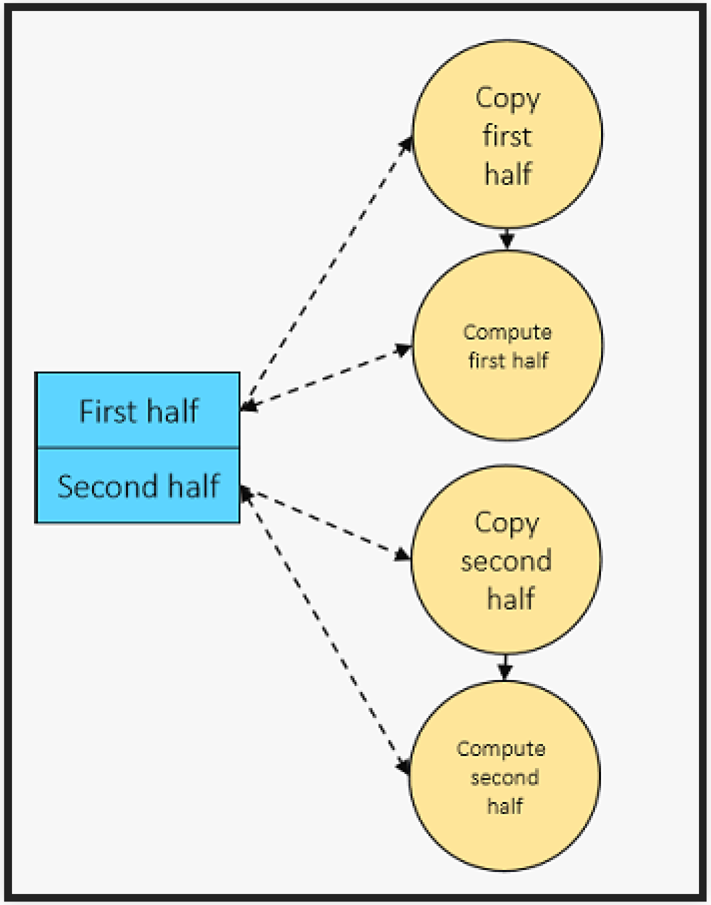
cpuQueue.submit([&](handler &cgh){ // Copy second half
  auto ptr = bufB.get_access<access::mode::read>(cgh);
  cgh.copy(data, ptr);});

cpuQueue.submit([&](handler &cgh){ // Compute first half
  auto ptr = bufB.get_access<access::mode::read_write>(cgh, halfSize, origin)
  cgh.parallel_for(range<1>(dA.size()), func(ptr)); });

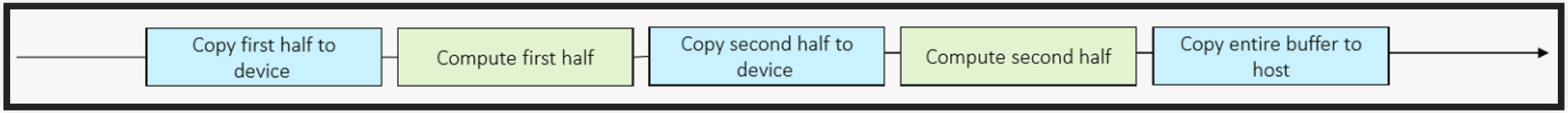
cpuQueue.wait_and_throw();
```



The first copy and compute operate on the first half of the buffer and the other copy and compute operate on the second half



- Each region of data is copied and then that region is computed
  - The entire buffer is copied back to the host at the end


Copy first half to device
Compute first half
Copy second half to device
Compute second half
Copy entire buffer to host