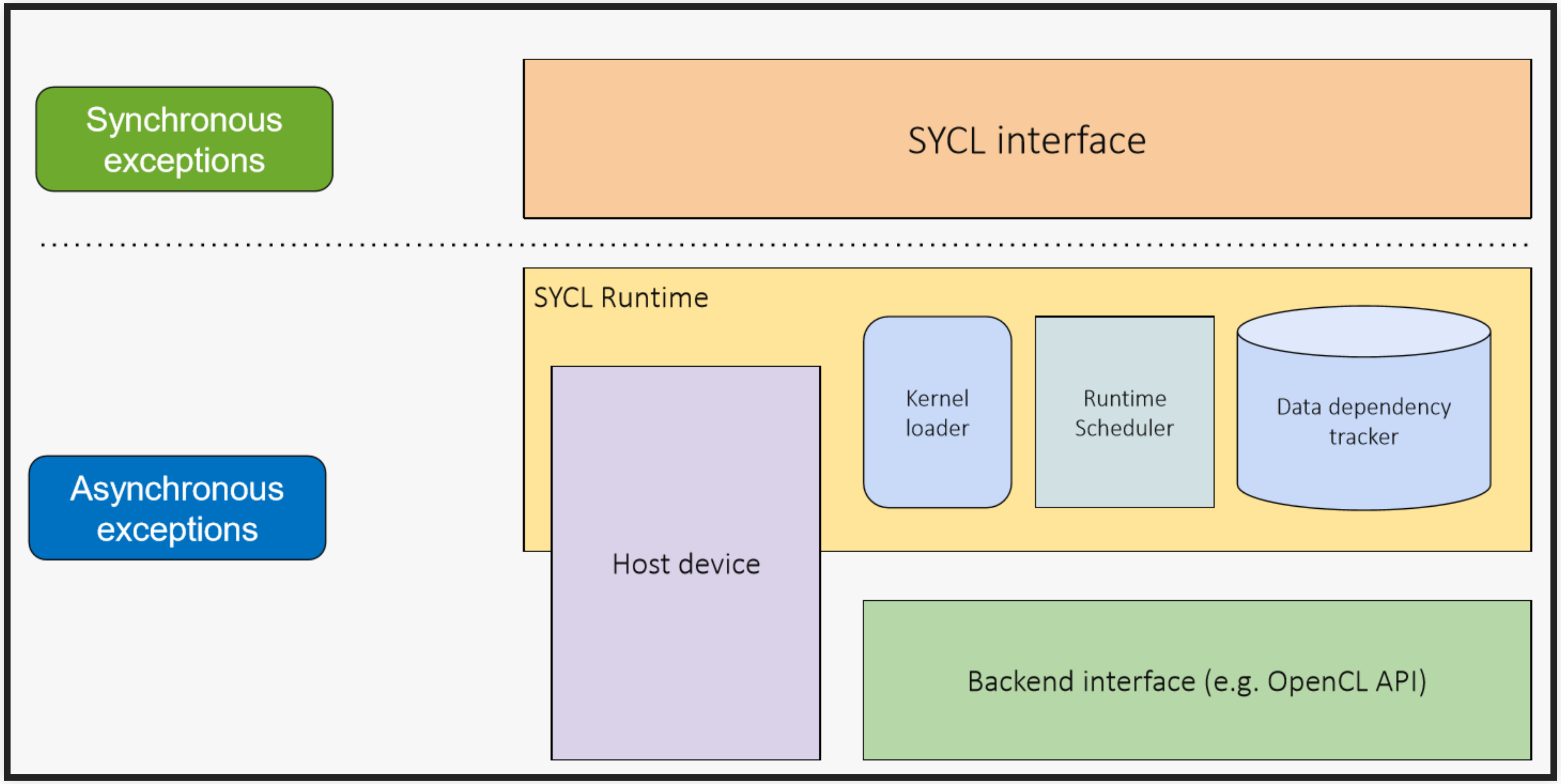
HANDLING SYCL ERRORS

LEARNING OBJECTIVES

- Learn about how SYCL handles errors
- Learn about the difference between synchronous and asynchronous exceptions
- Learn how to handle exceptions and retrieve further information
- Learn about the different exception types
- Learn about the host device and how to use it

- In SYCL errors are handled by throwing exceptions
  - It is crucial that these errors are handled otherwise your application may silently fail
- In SYCL there are two kinds of error
  - Synchronous errors (thrown in user thread)
  - Asynchronous errors (thrown by the SYCL scheduler)


Synchronous exceptions
SYCL interface
SYCL Runtime
Kernel loader
Runtime Scheduler
Data dependency tracker
Asynchronous exceptions
Host device
Backend interface (e.g. OpenCL API)

HANDLING ERRORS

```
#include <CL/sycl.hpp>
using namespace cl::sycl;
class add;

int main(int argc, char *argv[]) {
  std::vector<float> dA{ 7, 5, 16, 8 }, dB{ 8, 16, 5, 7 }, dO{ 0, 0, 0, 0 };
  queue gpuQueue(gpu_selector{});

  buffer<float, 1> bufA(dA.data(), range<1>(dA.size()));
  buffer<float, 1> bufB(dB.data(), range<1>(dB.size()));
  buffer<float, 1> bufO(dO.data(), range<1>(dO.size()));

  gpuQueue.submit([&](handler &cgh){
    auto inA = bufA.get_access<access::mode::read>(cgh);
    auto inB = bufB.get_access<access::mode::read>(cgh);
    auto out = bufO.get_access<access::mode::write>(cgh);

    cgh.parallel_for<add>(range<1>(dA.size()), [=](id<1> i){
      out[i] = inA[i] + inB[i];
    });
  });
  gpuQueue.wait();
}
```

- If errors are not handled, the application can fail silently

```
int main(int argc, char *argv[]) {
  std::vector<float> dA{ 7, 5, 16, 8 }, dB{ 8, 16, 5, 7 }, dO{ 0, 0, 0, 0 };
  try{
    queue gpuQueue(gpu_selector{});

    buffer<float, 1> bufA(dA.data(), range<1>(dA.size()));
    buffer<float, 1> bufB(dB.data(), range<1>(dB.size()));
    buffer<float, 1> bufO(dO.data(), range<1>(dO.size()));

    gpuQueue.submit([&](handler &cgh){
      auto inA = bufA.get_access<access::mode::read>(cgh);
      auto inB = bufB.get_access<access::mode::read>(cgh);
      auto out = bufO.get_access<access::mode::write>(cgh);

      cgh.parallel_for<add>(range<1>(dA.size()), [=](id<1> i){
        out[i] = inA[i] + inB[i];
      });
    });
    gpuQueue.wait();
  } catch (...) { /* handle errors */ }
}
```

- Synchronous errors are typically thrown by SYCL API functions
- In order to handle all SYCL errors you must wrap everything in a try-catch block

```
int main(int argc, char *argv[]) {
  std::vector<float> dA{ 7, 5, 16, 8 }, dB{ 8, 16, 5, 7 }, dO{ 0, 0, 0, 0 };
  try{
    queue gpuQueue(gpu_selector{}, async_handler{});

    buffer<float, 1> bufA(dA.data(), range<1>(dA.size()));
    buffer<float, 1> bufB(dB.data(), range<1>(dB.size()));
    buffer<float, 1> bufO(dO.data(), range<1>(dO.size()));

    gpuQueue.submit([&](handler &cgh){
      auto inA = bufA.get_access<access::mode::read>(cgh);
      auto inB = bufB.get_access<access::mode::read>(cgh);
      auto out = bufO.get_access<access::mode::write>(cgh);

      cgh.parallel_for<add>(range<1>(dA.size()), [=](id<1> i){
        out[i] = inA[i] + inB[i];
      });
    });
    gpuQueue.wait_and_throw();
  } catch (...) { /* handle errors */
}
```

- Asynchronous errors errors that may have occurred will be thrown after a command group has been submitted to a queue
  - To handle these errors you must provide an async handler when constructing the queue object
- Then you must also call the **throw_asynchronous or wait_and_throw** member functions of the queue class
- This will pass the exceptions to the async handler in the user thread so they can be thrown

```
int main(int argc, char *argv[]) {
  std::vector<float> dA{ 7, 5, 16, 8 }, dB{ 8, 16, 5, 7 }, dO{ 0, 0, 0, 0 };
  try{
    queue gpuQueue(gpu_selector{}, [=](sycl::exception_list eL) {
      for (auto e : eL) { std::rethrow_exception(e); }
    });

    buffer<float, 1> bufA(dA.data(), range<1>(dA.size()));
    buffer<float, 1> bufB(dB.data(), range<1>(dB.size()));
    buffer<float, 1> bufO(dO.data(), range<1>(dO.size()));

    gpuQueue.submit([&](handler &cgh){ // Command group submitted to queue
      auto inA = bufA.get_access<access::mode::read>(cgh);
      auto inB = bufB.get_access<access::mode::read>(cgh);
      auto out = bufO.get_access<access::mode::write>(cgh);

      cgh.parallel_for<add>(range<1>(dA.size()), [=](id<1> i){
        out[i] = inA[i] + inB[i];
      });
    });
    gpuQueue.wait_and_throw(); } catch (...) { /* handle errors */ }
}
```

- The async handler is a C++ lambda or function object that takes as a parameter an **exception_list**
- The exception_list class is a wrapper around a list of **exception_ptrs** which can be iterated over
- The exception_ptrs can be rethrown by passing them to **std::rethrow_exception**

```
int main(int argc, char *argv[]) {
  std::vector<float> dA{ 7, 5, 16, 8 }, dB{ 8, 16, 5, 7 }, dO{ 0, 0, 0, 0 };
  try {
    queue gpuQueue(gpu_selector{}, [=](sycl::exception_list eL) {
      for (auto e : eL) { std::rethrow_exception(e); }
    });
  ...
    gpuQueue.wait_and_throw();
  } catch (std::exception e) {
    std::cout << "Exception caught: " << e.what()
        << std::endl;
  }
}
```

- Once rethrown and caught, a SYCL exception can provide information about the error
- The **what** member function will return a string with more details

```
int main(int argc, char *argv[]) {
  std::vector<float> dA{ 7, 5, 16, 8 }, dB{ 8, 16, 5, 7 }, dO{ 0, 0, 0, 0 };
  try {
    queue gpuQueue(gpu_selector{}, [=](sycl::exception_list eL) {
      for (auto e : eL) { std::rethrow_exception(e); }
    });
  ...
    gpuQueue.wait_and_throw();
  } catch (std::exception e) {
    std::cout << "Exception caught: " << e.what();
    std::: cout << " With OpenCL error code: "
     << e.get_cl_code() << std::endl;
  }
}
```

- If the exception has an OpenCL error code associated with it this can be retrieved by calling the get_cl_code member function
- If there is no OpenCL error code this will return CL_SUCCESS

```
int main(int argc, char *argv[]) {
  std::vector<float> dA{ 7, 5, 16, 8 }, dB{ 8, 16, 5, 7 }, dO{ 0, 0, 0, 0 };
  try {
    queue gpuQueue(gpu_selector{}, [=](sycl::exception_list eL) {
      for (auto e : eL) { std::rethrow_exception(e); }
    });
  ...
    gpuQueue.wait_and_throw();
  } catch (std::exception e) {
    if (e.has_context()) {
          if (e.get_context() == gpuContext) {
            /* handle error */
          }
        }
  }
}
```

- The **has_context** member function will tell you if there is a SYCL context associated with the error
- If that returns true then the **get_context** member function will return the associated SYCL context object

EXCEPTION TYPES

- In SYCL there are a number of different exception types that inherit from **std::exception**
  - E.g. runtime_error, kernel_error
- The SYCL 1.2.1 specification will detail cases where a specific error can be expected

SYCL Academy

DEBUGGING SYCL KERNEL FUNCTIONS

- Every SYCL implementation is required to provide a host device
    - This device executes native C++ code but is guaranteed to emulate the SYCL execution and memory model
- This means you can debug a SYCL kernel function by switching to the host device and using a standard C++ debugger
    - For example gdb

```
int main(int argc, char *argv[]) {
  std::vector<float> dA{ 7, 5, 16, 8 }, dB{ 8, 16, 5, 7 }, dO{ 0, 0, 0, 0 };
  try{
    queue hostQueue(host_selector{}, async_handler{});
    buffer<float, 1> bufA(dA.data(), range<1>(dA.size()));
    buffer<float, 1> bufB(dB.data(), range<1>(dB.size()));
    buffer<float, 1> bufO(dO.data(), range<1>(dO.size()));

    hostQueue.submit([&](handler &cgh){
      auto inA = bufA.get_access<access::mode::read>(cgh);
      auto inB = bufB.get_access<access::mode::read>(cgh);
      auto out = bufO.get_access<access::mode::write>(cgh);

      cgh.parallel_for<add>(range<1>(dA.size()),
       [=](id<1> i){out[i] = inA[i] + inB[i];});
    });
    gpuQueue.wait_and_throw();
  } catch (...) { /* handle errors */ }
}
```

- Any SYCL application can be debugged on the host device by switching the queue for a host queue
- By replacing the device selector for the host_selector will ensure that the queue submits all work to the host device